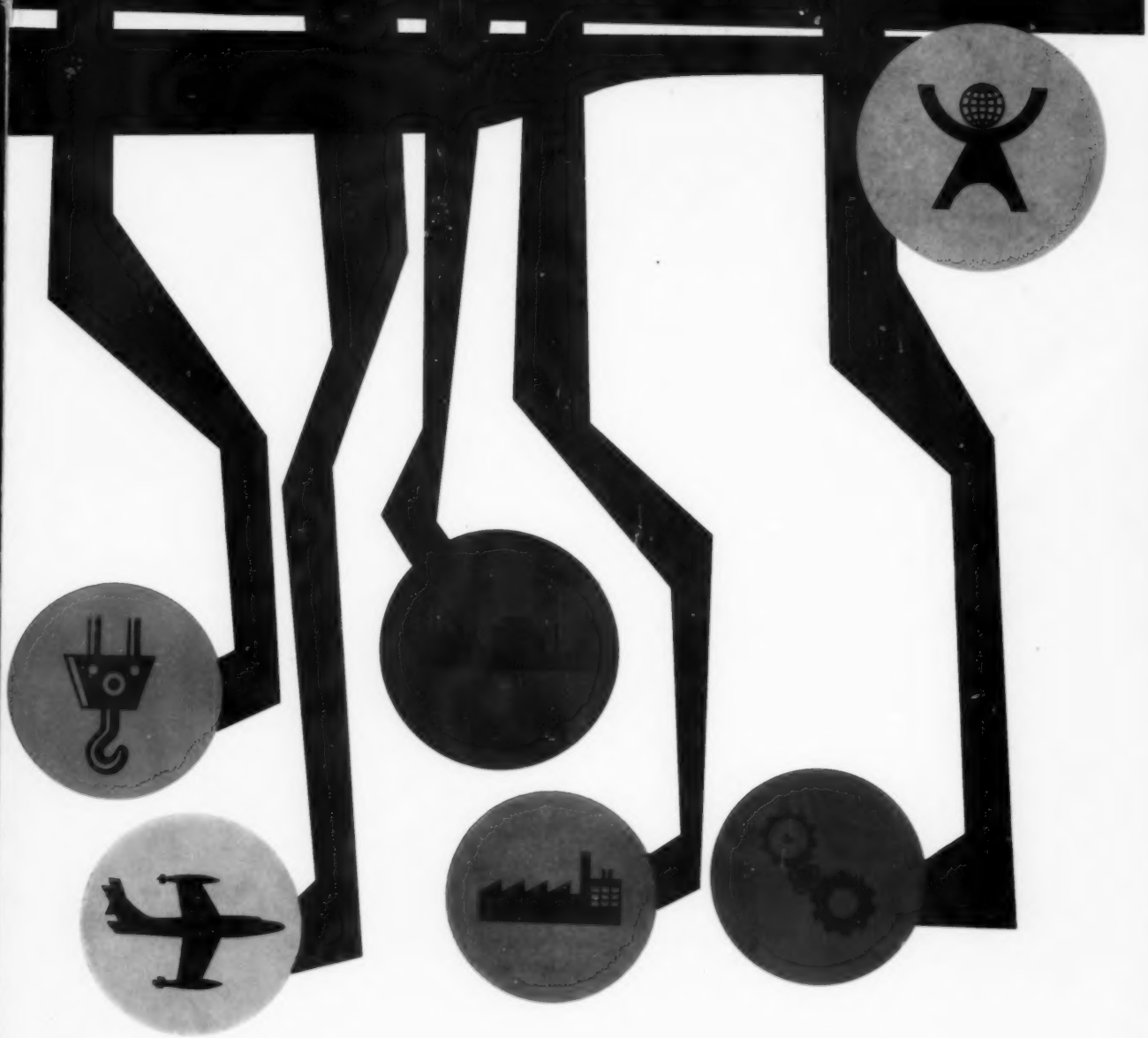
metal progress



October 1959

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FLAW DETECTION...
CLEANING...

ECONOMY: standard equipment adaptable to individual requirements • **DEPENDABILITY:** simple, rugged designs proven by years of use • **SERVICE:** factory-trained specialists before, during, after installation.

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Models 14, 21, and R (Automatic). Range 0.004′ to 2.7″, accuracies from 1/2 to 1/50 of 1%. Bright image on large CR tube with interchangeable scales. Simple setup, no elaborate fixtures. Extension cables and intercom phones for remote work up to 1/5 mile from basic instrument. Wide choice of transducer sizes, shapes, mountings. Bulletin V-200.

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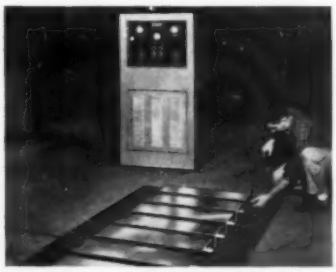
In many models and combinations of standard units from 1/2-gallon to hundreds-of-gallons capacity. Laboratory-size, roll-around, modular-cabinet, built-in and engineered systems to meet any cleaning requirement with equipment proven in years of use. Bulletin S-200.



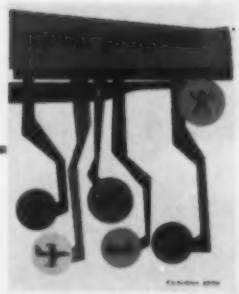
See PICKLING • GAGING • FLAW-DETECTION

BOOTH 1645

Branson • 65 BROWN HOUSE ROAD • STAMFORD • CONNECTICUT

Metal Progress

October 1959 . . . Volume 76, No. 4



The cover design, depicting the industrial aspects of the Metal Show, was produced by Student ALLEN PUCELL in the annual competition sponsored by *Metal Progress* at the Cleveland Institute of Art.

National Metal Congress and Exposition

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Technical Programs 68

For seven days, Saturday through Friday (Oct. 31 through Nov. 6), visitors to the Metal Congress will have a wide choice of metallurgical education and technology in sessions presented by the American Society for Metals, the Metallurgical Society of A.I.M.E., Society for Nondestructive Testing, Ultrasonic Manufacturers Association, Metals Division of Special Libraries Association, Metal Treating Institute, and Metal Powder Industries Federation.

National Metal Exposition 89

List of exhibitors, booth numbers and brief descriptions of products.

Overcoming the Producibility Barrier

Producibility, the degree to which a part can be made economically in the quantities needed, is of great significance today to manufacturers of metal goods. All companies are faced with a severe problem of keeping costs in line to stay competitive. There is pressure from increasing wages and higher cost materials. To compensate for these, manufacturers must look to improved technology for new ideas which will increase the efficiency of their production operations. This special "metal month" feature offers many suggestions for overcoming producibility problems. Techniques developed to solve a problem in one industry can often benefit other manufacturers.

Overcoming the Producibility Barrier by Improved Forming Techniques

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This is THERMAL FATIGUE

This photograph shows a heat-resistant alloy casting after thermal-fatigue failure.

Thermal fatigue begins with cyclical heating and cooling which produces alternate expansion and contraction. The shape of the casting hinders this expansion and contraction. As a result, hindered expansion and contraction stresses develop and increase until plastic flow occurs. This plastic flow produces a network of thermal-fatigue cracks and this cracking leads to failure.

Thermal fatigue is an inherent problem in heat-resistant castings. As such, it occupies an important place in Electro-Alloys research efforts to lengthen life of components working under high temperatures and severe cyclical conditions.

We have created apparatus that assesses and analyzes the variables of thermal fatigue. Check with your Electro-Alloys representative for the meaning of our thermal fatigue data as it pertains to the material, design and service conditions of your heat-resistant castings.

View and discuss Thermal Fatigue at the Electro-Alloys Booth, 727, National Metals Exposition, International Amphitheatre, Chicago, November 2-6.

Send for free technical booklet on Thermal Fatigue

Please send me free copy of "The Mechanism of Thermal Fatigue," by Howard S. Avery—comprehensive report based on extensive lab studies:

Name_____

Title_____

Company_____

Address_____

City_____ State_____

Electro-Alloys, 10110 Taylor St., Elyria, Ohio

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

Metal Progress

Overcoming the Producibility Barrier by More Suitable Selection of Alloys

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Standard Commercial Wrought Copper and Copper-Base Alloys **128-B**

Composition, forms and specifications, mechanical property ranges, fabricating characteristics and typical uses; information supplied by Copper & Brass Research Association.

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AUGUST—Selected supplier of anhydrous ammonia . . . assuming that service included technical advice "during use".

LATER—Ammonia system installed without supervision . . . not tested by supplier . . . some parts not designed for ammonia use.

STILL LATER—Had improper atmosphere mixture . . . undesirable case properties . . . sooting and added handling of "finished" parts.

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Press Breaks...

FROM TIME TO TIME the Editors receive letters from readers asking why *Metal Progress* does this or that, and some of these may have rather general interest. For example:

Front Covers – One of the objectives in the organization of *Metal Progress* in 1930 was to create a magazine which had high excellence, typographically as well as technically. The financial stringency we passed through very shortly (the well-known depression) did not alter our resolve – in fact, the low state of morale of metallurgists generally reinforced our desire to present them a quality magazine each month in keeping with the dignity and worth of their profession.

Another reason for giving the magazine an attractive front cover is that about four fifths of the members of the Society have it sent direct to their homes, and there it must compete for attention with "slick" magazines of general circulation. A shoddy looking cover on a magazine will invite it to be chucked out with the morning paper.

We were also fortunate, about 15 years ago, in becoming acquainted with Otto Egge, then head of the department of commercial art at the Cleveland Institute of Art (our well-known art school). He suggested that an annual competition for a front cover would represent a desirable pedagogical project, and this competition has been held every year since then. We get a number of our covers in this way, but the prizes and supplementary checks the students receive are the equal to what a commercial artist would get for a design.

Other covers are prepared from full color transparencies or photographs which depict, in an artistic manner, an operation or technique of interest to *Metal Progress* readers. Perhaps you have something along this line which you would like to submit for cover consideration. If so, we will be glad to hear from you.

Advertising Section – "I greatly enjoy *Metal Progress*. If it is any embarrassment to the reader, surely it is its weight, for while you pack a very substantial volume of useful metallurgical articles and data, you send along an even greater weight of glossy advertising matter." This comment that we carry a lot of advertising matter is fortunately true – it is the fuse which makes the engine go. In fact (outside of a few hundred subscriptions by nonmembers) it is our only source of income. For 20 years, this actually has exceeded our production expense by a margin sufficient to pay for the other deficit-producing publications of the American Society for Metals, namely, *Transactions*, *Metals Review*, and *Review of Metal Literature*.

Tear Sheets – To a reader who wished the data sheets and feature articles to be perforated near the backbone for ready removal, so as to "avoid the storage problem of filing the whole magazine", the Editor-in-Chief replied by citing his own experiences:

"When I first entered the editorial profession, now about 40 years ago, I started the practice of tearing out valuable articles from current periodicals in English which passed my desk. These articles were then segregated and filed by topic. As years passed, my interests altered and expanded, so that before long this "data file", as we called it, became a rather formidable thing. When "*Review of Metal Literature*" was started by the American Society for Metals, in 1944, further additions ceased, since we found that information on specific topics could quickly be run down by reference to the current issues of "*Review of Metal*

BRUSH BERYLLIUM BULLETIN

application and fabrication news

HIGH TEMPERATURE PROPERTIES OF BERYLLIUM-COPPER ALLOYS

The high temperature properties of all beryllium-copper alloys are being studied in a long range testing program at BRUSH BERYLLIUM. To take several years to completion, this program is reported regularly to users in progress reports listing data for a single set of properties. PROGRESS REPORT #1 gave the HOT-HARDNESS characteristics of four casting alloys. PROGRESS REPORT #2, now in preparation, describes TENSILE STRENGTH at ELEVATED TEMPERATURES. The entire program will cover HOT HARDNESS, HOT TENSILE STRENGTH and HOT FATIGUE STRENGTH of four casting alloys and four wrought alloys.

BEATING THE HEAT WITH BERYLLIUM

One of the big problems in orbiting a manned satellite is RE-ENTRY heat. Atmospheric friction at high re-entry speeds will cause disastrous heat in the satellite unless properly shielded. In PROJECT MERCURY, N.A.S.A. is studying two methods, ABLATION and HEAT-SINK. For the heat-sink tests, in which large amounts of heat must be absorbed quickly by the shield, BERYLLIUM was the material selected. High heat capacity, high thermal conductivity, high strength at elevated temperatures and light weight are combined only in BERYLLIUM, making it the best heat-sink material for air-borne applications.

BRUSH is producing a series of forgings, 74" in diameter, for McDONNELL AIRCRAFT CORPORATION, designer and builder of the PROJECT MERCURY SPACE CAPSULE. These forgings, the largest ever produced, were designed on the basis of BRUSH's prior experience in the hot-working of beryllium, experience which includes years of development of techniques for hot-rolling, forging, upsetting and extrusion.

THE Brush Beryllium COMPANY
4301 PERKINS AVENUE
CLEVELAND 3, OHIO

SEE WHY...
THE TREND
IS TO UNITRON!

VISIT BOOTH 820
41st NATIONAL METALS EXPOSITION
CHICAGO, ILL. NOV. 2-6, 1959

For a preview of UNITRON's line of microscopes see page 49. We invite you to bring your samples and specimen along for visual examination and photomicrography.

Our optical engineers will gladly discuss your individual problems and suggest suitable instruments for your purpose.

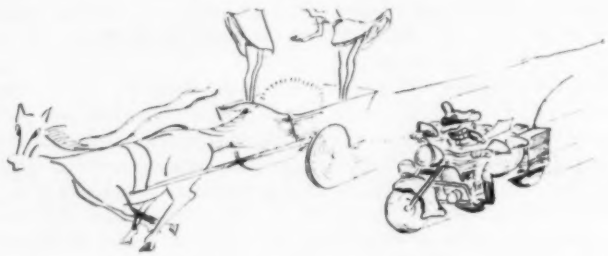
UNITRON
INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO.
204-206 MILK STREET • BOSTON 9, MASSACHUSETTS

Press Breaks . . .

Literature". By that time, my data file had grown to where it occupied 30 full-size drawers. Consequently, any scheme of removing tear sheets, if systematically carried out, will eventually pose a very serious storage problem. As far as the task of removing articles from current issues is concerned, I have never found the least difficulty in doing this with the sharp blade of my good old pocket knife."

Critical Points – *Query:* "Would it not be a good idea to expand your 'Critical Points' into more comprehensive critical reviews?" *Answer:* "The term 'Critical Point' is supposed to be a cute metallurgical term which *Metal Progress* uses in place of the standard word 'Editorial'. Critical Points was started at least 20 years ago when the editor found that so much of his travel throughout American industry did not result in prompt copy. In fact the amount which actually got into print was discouragingly low. He would see interesting new things, and the people responsible for them would promise to write an article, but either would never get around to it, or would write up a story for one of our competitors with a larger budget for contributed articles or a larger editorial staff. He consequently started the plan of recording immediately his impressions from such visits, submitting his manuscript back to friends in the respective plants before printing them, and getting into the record *immediately* the things he thought worthy of comment. These are 'Critical Points'. Frequently they briefly record important advances a full year before anyone gets around to writing about them in detail."

Apropos of Bruce Rogers' witty contribution in the "Light Metallurgy" department last November ("Preposition Using by Metallurgists"), already reprinted by the Breakfast Commentator in the Cleveland *Plain Dealer*, G. W. Weeks sends the following note and sketch from Hatfield, England: "I suggested to my staff that, as a lunchtime recreation, using pen and paper, they might produce a very simple illustration of the phrase 'The mouse was caught using a trap'. You may be interested to see one of the more enlightened efforts. Clearly, there is more than one way of using the English language!"



We wonder how many readers of *Metal Progress*, in this automotive age of motor-cop traps, remember that a two-wheeled, one-horse carriage was once called a "rattle trap" or, more simply, just a "trap"!

This column is being written a few days early to allow extra production time for this big Metal Show issue. We believe you will find much helpful information in the section developed specifically for this occasion on "Overcoming the Producibility Barrier" – ideas to help you do a better job in metal selection and production. The program (p. 68) is arranged as a day-to-day calendar to assist you in planning your time in Chicago. We will be on hand in A.S.M. Booth 810 in the South Hall of the International Amphitheatre. It will be easy to find right next to the main registration area – so drop by to see us while you are at the Show.

THE EDITORS

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ALLEN G. GRAY, *Editor*

MARJORIE R. HYSLOP, *Managing Editor*

Assistant Editors
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METALS PARK, NOVELTY, OHIO, JORDAN 4-2271

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Publishes *Metals Handbook*, an encyclopedia of metals; *Metals Review*, news magazine; *Review of Metal Literature*, abstracting service; *Transactions*, scientific annual; Career technical books on metals.

Educational activities: Operates National Western, and Southwestern Metal Congresses and Expositions; prepares and administers courses for Metals Engineering Institute for home, in-plant or American Society for Metals Chapter study.

READERSHIP Eastman RESEARCH

Metal Progress is available on microfilm from University Microfilms, Ann Arbor, Mich.

STRAITS TIN REPORT

News of developments in the production and uses of tin

MALAYAN TIN BUREAU

New "cartridge-type" alloy bearings of tin, copper, lead and zinc will soon go into service on freight cars after 2 years of tests on U.S. railroads. Life expectancy of new bearing is said to be 25 years—compared to 3½ years for conventional bearings. It will require only minimum maintenance.

Greater creep resistance—that is the quality imparted to titanium with the addition of tin. Some titanium alloys contain as much as 22.5% tin. The most successful contains 2.5% tin and 5% aluminum. It is principally used for jet aircraft parts requiring maximum strength in the range of 600-1100°F.; in high-strength welded assemblies; and in jet engine combustion chamber casing and other uses requiring a better combination of toughness, fatigue strength, and creep resistance at elevated temperatures.

Electrodeposited coatings of tin-zinc have aided in solving auto fuel system problems caused by corrosive action of some fuels on carburetor parts.

A tin-cadmium alloy coating, according to research reports, has excellent resistance to salt spray, jet fuels, high temperature synthetic oils, organic acid vapors; very little embrittling effect on hardened steel.

Write today for more data on these items or for a free subscription to TIN NEWS—a monthly bulletin on tin supply, prices and new uses.

The Malayan Tin Bureau
Dept. 25K, 1028 Connecticut Ave., Washington 6, D.C.

1470 AB

HANDIMET GRINDER

A New, Wet Hand Grinder for Metallurgical Samples

Now you may have wet grinding facilities for hand preparation in your laboratory at a nominal cost. Convenience at your fingertips, always clean and ready for use. Simply attach to water and drain facilities.

Individual elevated hard glass grinding surfaces are continually flushed with streams of water. This floats off the surface removal products, provides lubrication, and leaves sharp abrasive edges exposed at all times. A control valve permits complete selectivity of the volume of water. Ample drainage facilities with standard pipe fittings are provided at the rear. The grinding platforms are pitched downward and away from the operator.

The Handimet Grinding Paper is coated with a pressure sensitive adhesive backing and firmly holds when merely pressed against the flat grinding surface. It is easily removable when sheet is worn.

See Buehler Products
Booth 415
National Metal Exposition
Chicago, Nov. 2-6, 1959

Buehler Ltd.

METALLURGICAL APPARATUS

2120 GREENWOOD ST., EVANSTON, ILLINOIS, U.S.A.

On Exhibit at the Metal Show...

two important new developments by

LINDBERG

Visit Lindberg Booth 520 at the Metal Show and see these latest developments by Lindberg engineers.

The New Lindberg Floating Zone Scanner (shown at the left) has been expertly designed to provide more accurate and precise production of high purity semi-conductors and metals. It is an ideal tool for metallurgical research and production of semi-conductor devices.

The new high temperature Graphite Tube Furnace, (shown below) has been developed to meet the demand for higher controlled temperatures for research and small production in the metallurgical and ceramic fields. Its temperature range of 1600° F. to 5000° F. makes it ideal for sintering of powdered metals, firing of ceramic bodies and high temperature chemical reactions.

LINDBERG **heat for industry**

For full information on the new Floating Zone Scanner ask our High Frequency Division for Bulletin No. 1600.

For full information on the new Graphite Tube Furnace ask our Pilot Plant Equipment Division for Bulletin No. T-1084.

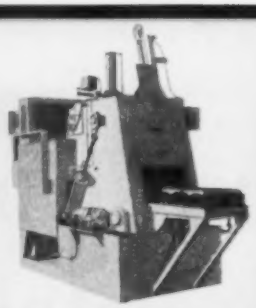
LINDBERG ENGINEERING CO.

2448 West Hubbard Street, Chicago 12, Ill.

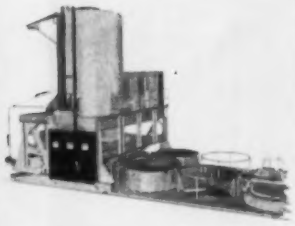
Los Angeles Plant: 11937 South Regentview Avenue, at Downey, California

In Canada: Efco-Lindberg, Ltd., Toronto

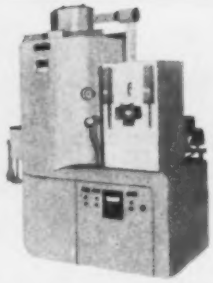
Laboratory Equipment: One-unit box furnace (shown), muffle or for non-oxidizing atmosphere with temperature range to 3000° F.



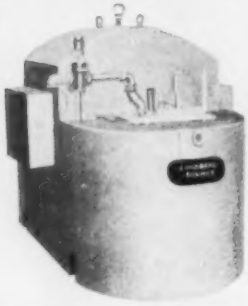
Automatic Carbonitriding Furnaces: Automated integral quench type (shown) with CORRTHERM electric elements.



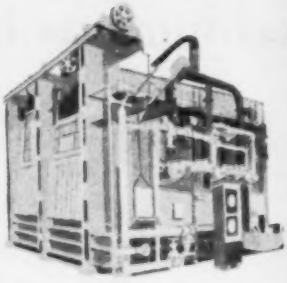
Gantry Type Furnaces: Vertical, controlled-atmosphere, drop bottom, hardening furnace (shown). Complete installation field-installed by Lindberg.



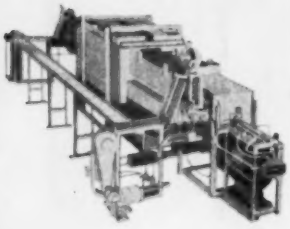
Atmosphere Generators: Hyen generator (shown) for endothermic atmospheres. Generators for all required atmospheres.



Melting and Holding Furnaces: Electric resistance furnace (shown) with capacities of 750 lbs. to 1500 lbs.



Aluminum Reverberatory Furnaces: Twin-chamber melting and holding furnace (shown) with 45,000 lbs. capacity.



Ceramic Kilns: Fully automatic, atmosphere controlled kiln (shown) has 5 control zones for flexibility. Maximum temperature, 2700° F.

Cyclone Tempering Furnaces: Batch type fuel fired tempering furnace (shown). Famous in metal treating industry for years.

When a product needs heat let Lindberg apply it

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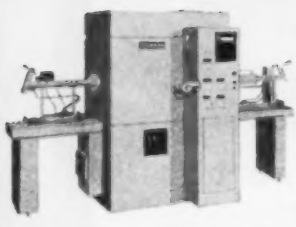

High Temperature Furnaces: New Graphite Tube Furnace (shown) with temperature range 2600° F. to 5000° F. for research and production in metal and ceramic fields.

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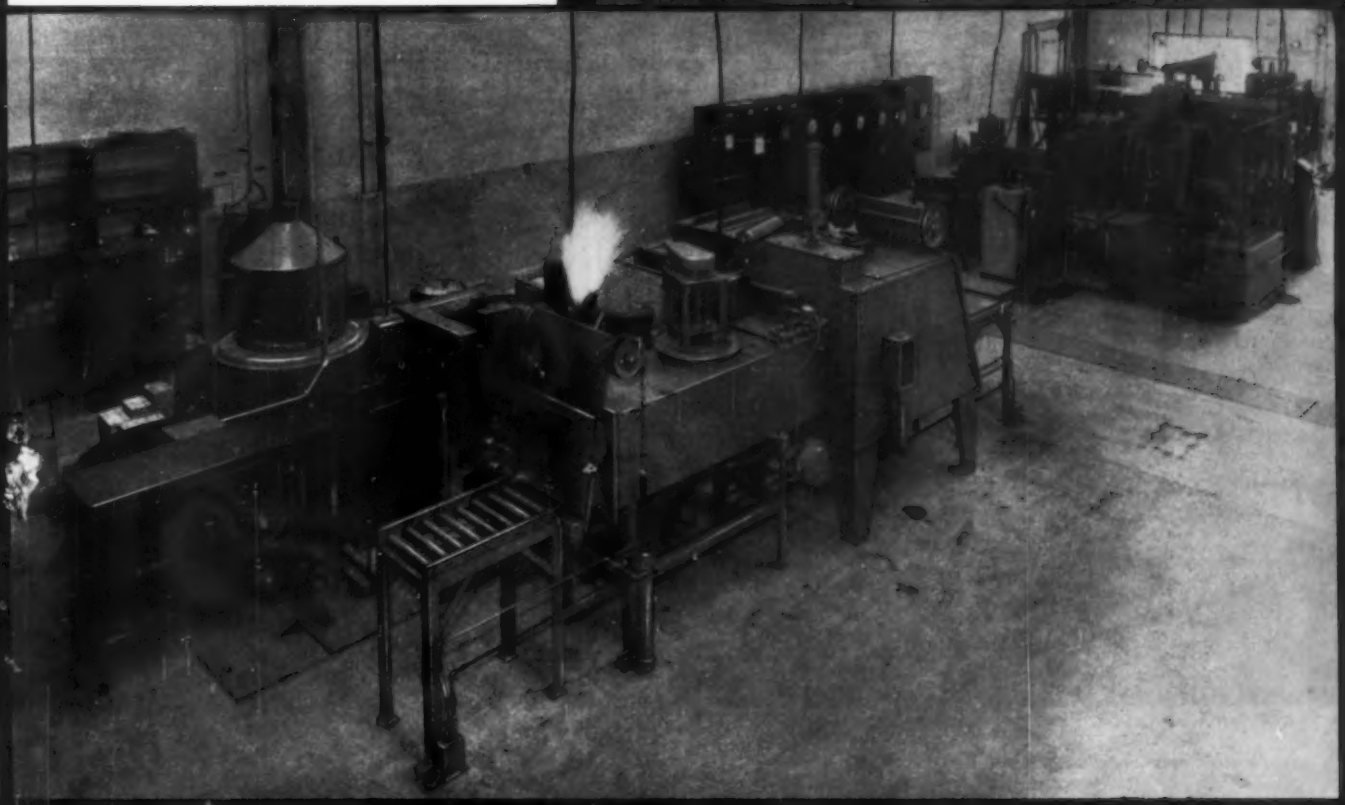

General view of complete Heat Treating Department at new plant of Lear, Inc., Grand Rapids, Michigan. All equipment including furnaces, Hyen atmosphere generator, control panels, oil quench is by Lindberg.

Electric atmosphere brazing and annealing furnace. Hand pusher type . . . 2100° F. maximum temperature.

Electric pit furnace for treatment of high temperature alloys in dry hydrogen atmosphere. Tap transformer also shown.

The retort for high temperature pit furnace for treatment of alloys at 2200° F. (left). Production tempering furnace, 22" x 26" work space, shown at right.

Atmosphere tempering furnace, 16" x 24" work space, for both gaseous nitriding and steam treating. One retort in foreground.

LINDBERG Equips Complete Heat Treating Department at Lear, Inc.

The heat treating requirements for the new Grand Rapids plant of Lear, Inc., were put into Lindberg's hands. We supplied them in the way the photographs show. Our engineers cooperated fully with Lear in the selection of the proper Lindberg equipment and the layout of the complete heat treating department. This installation illustrates one of the big advantages of consulting with Lindberg. Our years of experience in all phases of the application of heat to industry, our complete line of all types of industrial heating equipment offer the best assurance that you can coordinate all your needs in one reliable, experienced source. Consult your local Lindberg Field Representative (see classified phone book) or write us direct.

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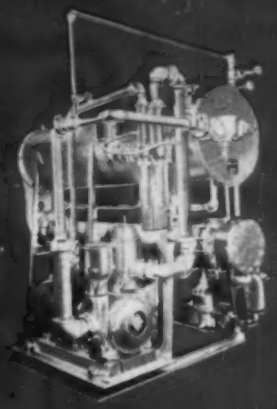
Lindberg Atmosphere Generators For Every Need

Pioneer in providing controlled atmospheres for heat treating, Lindberg offers atmosphere generators for every requirement

For details write for Bulletin No. 191

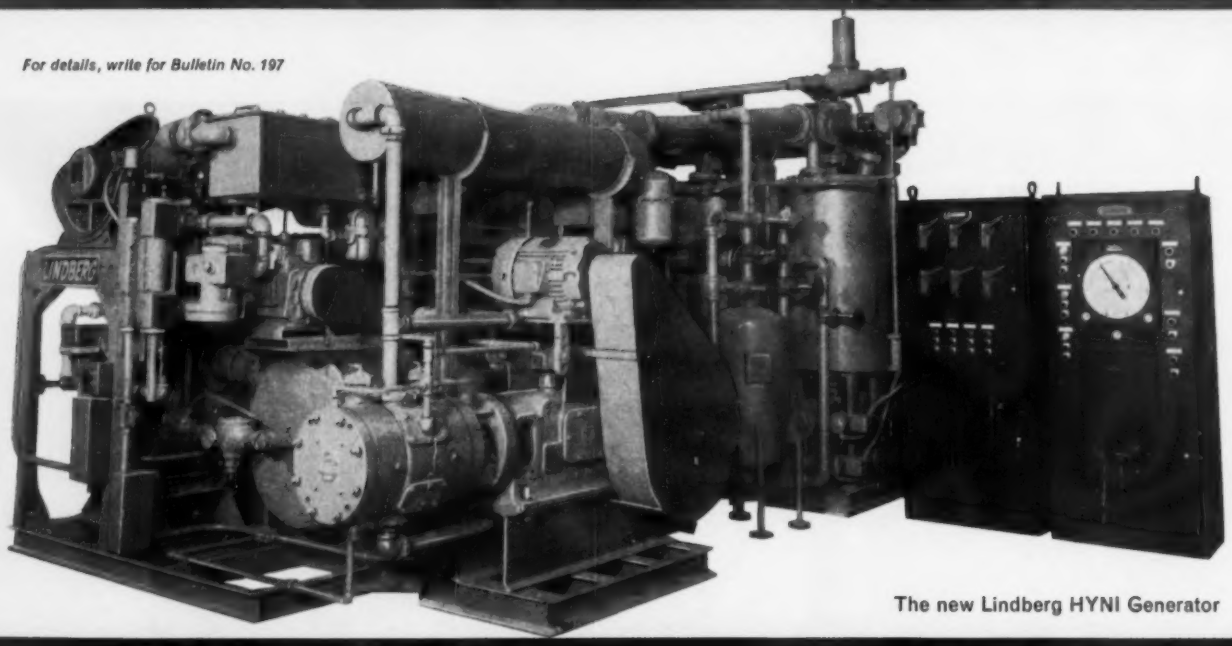
The HYEN GENERATOR is a fully automatic process for producing an inexpensive atmosphere for bright hardening, bright copper or silver brazing of medium and high carbon steels totally free from carburization or decarburization.



The HYEX GENERATOR is a process to automatically and inexpensively produce an atmosphere for bright annealing or brazing of non-ferrous metals or ferrous metals where decarburization is not a factor.

Also available, HYAM GENERATORS for producing a dry hydrogen-nitrogen mixture by ammonia dissociation

For details, write for Bulletin No. 197



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The new Lindberg HYNI Nitrogen Atmosphere Generator assures nitrogen of higher purity than has been achieved by other processes. It is capable of producing an atmosphere of 99.99% nitrogen through a completely new *dry* process. It uses the principle of burning a hydro-carbon fuel in a separate catalytic combustion chamber to obtain complete reaction without unburned methane, high residual oxygen or high percentages of oxides of nitrogen. Carbon dioxide, water vapor, sulphur dioxide or hydrogen sulphide are simultaneously removed in a dry, absorbent material known as Molecular Sieve made by Linde Division of Union Carbide and Chemical Corporation.

In the metals industry this superior nitrogen atmosphere is ideal for bright hardening, free from carburization and decarburization . . . annealing and normalizing without scale, decarburization or carburization . . . bright copper and silver brazing . . . carbon correction of decarburized forgings or bar stock . . . sintering of powder metals . . . gas carburizing and carbonitriding. It is also useful as a blanketing gas in the chemical, petroleum and food processing industries.

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Some of the problems of elevated temperature joint strength and oxidation resistance in heat-resistant alloys are being solved today by a relatively new group of Handy & Harman high temperature brazing alloys. These alloys embody certain unique characteristics, all of which are requisite for high temperature brazing:

- They have good strength and oxidation resistance at recommended temperatures.
- They are ductile, with the ability to withstand vibration and stress at elevated temperatures.
- These Handy & Harman alloys provide minimum solution and penetration of the metals being joined; this is a particular advantage when joining thin sections.
- These alloys effectively join stainless steels, low alloy steels, nickel-base alloys, cobalt-base alloys and other high temperature metals including refractory types.

The list of successful applications includes jet engine parts, heat exchangers, rocket motors, clad metals, honeycomb structures, turbine blades and many others. The following are brief descriptions of these Handy & Harman alloys:

LITHOBRAZE 925 For short time operation to 900° F, continuous at 500° F. Very ductile, virtually no solution of base metal. Good salt-spray corrosion resistance.

HI-TEMP 30 For continuous service 900° F-1000° F. Fairly ductile, moderate general solution of base metal.

PREMABRAZE 128 Continuous service up to 1500° F. Ductile, moderate solution of the base metal. Tensile strength at 1600° F in 304 stainless steel is 20,000 psi (short time test).

PREMABRAZE 130 Same properties as PREMABRAZE 128, but freer flowing and lower brazing temperature.

PREMABRAZE 101 Continuous operation in 1800° F-2000° F range (based upon limited oxidation tests). Ductile, moderate solution and penetration of the base metal.

Alloy	Nominal Composition	mp° F	fp° F
LITHOBRAZE 925	92.5 Ag 7.3 Cu .2 Li	1435	1635
HI-TEMP 30	70 Mn 30 Ni	1885	1920
PREMABRAZE 128	72 Au 22 Ni 6 Cr	1785	1900
PREMABRAZE 130	82 Au 18 Ni	1740	1740
PREMABRAZE 101	54 Pd 36 Ni 10 Cr	2250	2300

Data sheets and complete details on each of the above Handy & Harman alloys are available upon request to Handy & Harman, 82 Fulton Street, New York 38, N. Y.

Your NO. 1 Source of Supply and Authority on Brazing Alloys

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III

KNOW YOUR ALLOY STEELS . . .

This is the third of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

What Does Grain Size Mean In An Alloy Steel?

The grain size of alloy steels is generally understood to mean austenite or inherent grain size, as indicated by the McQuaid-Ehn carburizing test. Austenite grain size should be distinguished from ferrite grain size, which is the size of the grains in the as-rolled or as-forged condition with the exception of those steels that are austenitic at room temperature. When steel is heated through the critical range (approximately 1350 to 1600 deg F for most steels, depending on the composition), transformation to austenite takes place. The austenite grains are extremely small when first formed, but grow in size as the temperature above the critical range is increased, and, to a limited extent, as the time is increased. It is apparent, therefore, that both time and temperature must be constant in order to obtain reproducible results.

When temperatures are raised materially above the critical range, different steels show wide variations in grain size, depending on the chemical composition and the deoxidation practice used in making the heat. Heats are customarily deoxidized with aluminum, ferrosilicon, or a combination of deoxidizing elements. Steels using aluminum or other deoxidizers in carefully controlled amounts maintain a slow rate of grain growth at 1700 deg F, while heats finished with other deoxidizers, usually ferrosilicon, develop relatively large austenite grain size at temperatures somewhat below 1700 deg F.

The McQuaid-Ehn test is the one ordinarily used for determining grain size. Steel is rated with a set of eight ASTM charts that are compared one at a time with a specially prepared steel sample until one is found to match. Number 1 grain size, the coarsest, shows 1½ grains per sq in. of steel area examined at 100 diameters magnification. The finest chart is Number 8, which shows 96 or more grains per sq in. at the same magnification.

Properties Affected by Grain Size

Fine-grain steels (grain sizes 5, 6, 7, and 8) do not harden as deeply as coarse-grain steels, and they have less tendency to crack during heat-treatment. Fine-grain steels exhibit greater toughness and shock-resistance—properties that make them suitable for applications involving moving loads and high impact. Practically all alloy steels are produced with fine-grain structures.

Coarse-grain steels exhibit definite machining superiority. For this reason a few parts which are intricately machined are made to coarse-grain practice.

The correct specification and determination of grain structure in steel is a subject that has been given long study by Bethlehem metallurgists. If you would like suggestions on this or any other problem concerning alloy steels, these men will be glad to give you all possible help.

In addition to the entire range of AISI alloy steels, Bethlehem produces special-analysis steels and the full range of carbon grades.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

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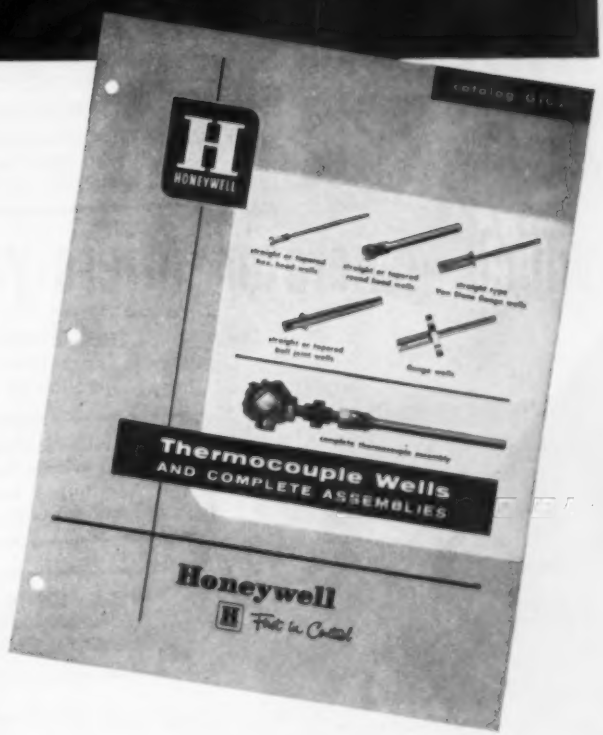
helps you choose the right

THERMOCOUPLE WELLS



Here's valuable help in the often-perplexing job of picking the right thermocouple wells and assemblies for particular applications.

This new Honeywell catalog brings you a wealth of useful data . . . provides all the information you need to make the right selection every time. Included in the catalog are:

- **Well designs and dimensions**
- **Pressure and temperature ratings**
- **Corrosion data**
- **Thermocouple assembly data**
- **Ordering and pricing information**

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THER-MONIC is the only induction heater that protects your investment!
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THER-MONIC is the only induction heater
. . . with a totally enclosed air-conditioned cabinet and a built-in heat exchanger that insures maximum efficiency.

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. . . with a variable-ratio output transformer, permitting the use of the widest range of work coils.

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. . . providing for 6000 KVA in tank circuit for efficient heating of non-magnetic metals.

THER-MONIC is the only induction heater
. . . with filament voltage regulation of 1%, assuring long tube life and precise repetitive production results.

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THER-MONIC is the only induction heater
. . . providing complete access for maintenance from two sides of the cabinet.

THER-MONIC is the only induction heater
. . . whose frequency can be increased to 5,000,000 cycles by minor modifications, for the jobs that are difficult to heat with conventional frequencies.

THER-MONIC is the only induction heater
. . . with electrical and mechanical interlocks for maximum safety to equipment and personnel.

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Sept.-Oct. 1959

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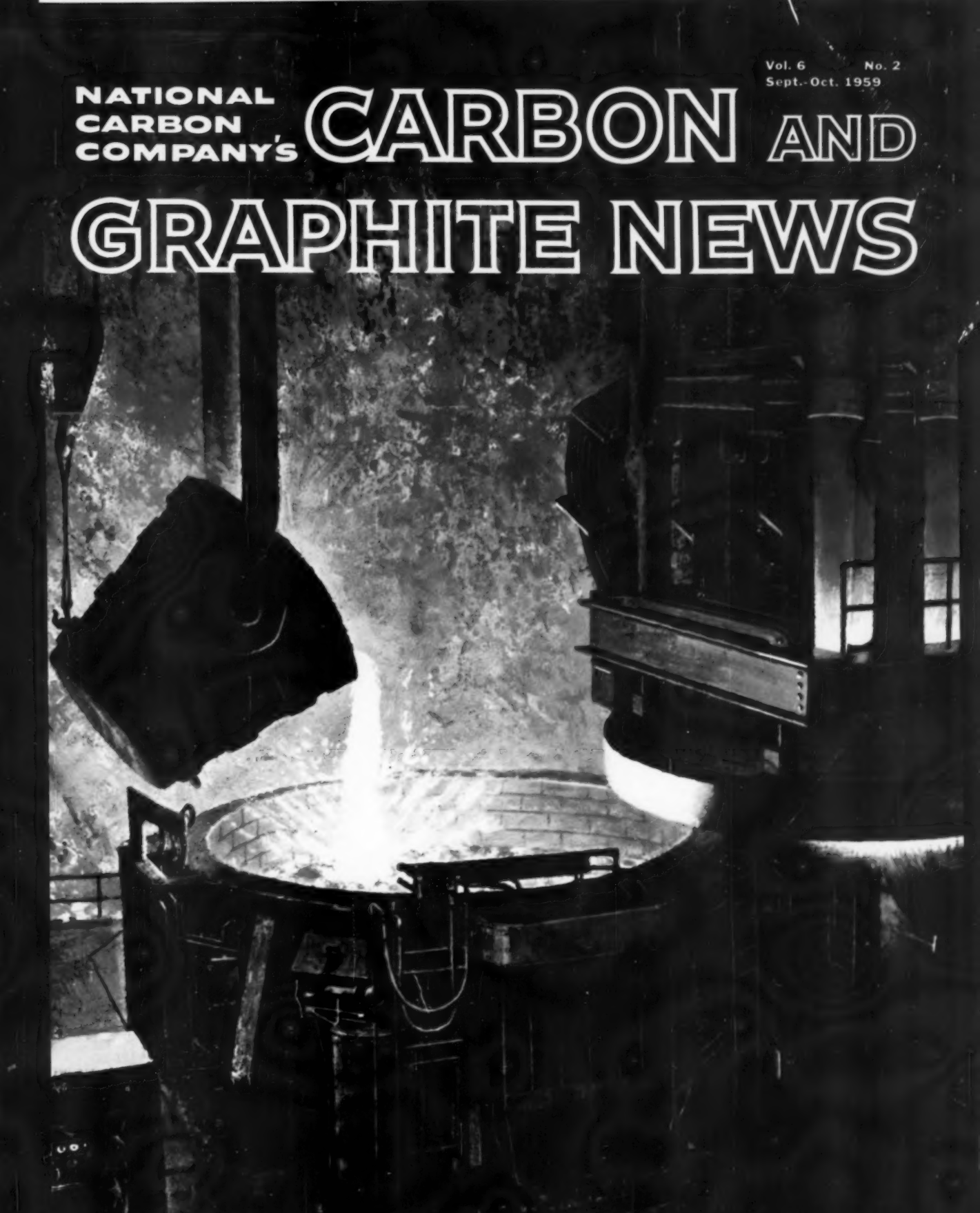

HOT METAL IN THE ELECTRIC ARC FURNACE

By R. Durrer and G. Heintze

HOT METAL IN THE ELECTRIC ARC FURNACE

By R. Durrer and G. Heintze

R. Durrer, *Managing Director*
G. Heintze, *Chief Metallurgist*
Gesellschaft der Ludw. von Roll'schen Eisenwerke AG, Gerlafingen, Switzerland

Introduction

This article is intended as a contribution to the direct refining of liquid pig iron in electric arc furnaces. The Frick-tal ore considered for smelting resembles in composition the Minette ore of Lorraine and produces a pig iron of high phosphorus content. In recent years, tests have been conducted at the Gerlafingen (Switzerland) steelworks of Ludw. von Roll'schen Eisenwerke AG, to refine liquid pig iron, and in particular high-phosphorus pig iron, in the arc furnace. Within the framework of the tests reported in this paper, low- and high-phosphorus pig irons were charged as up to 70% of the total charge weight in 12-ton and 40-ton arc furnaces, using ore as the main refining agent.

Ore Refining Problems

The main problem in using ore as the refining agent is control of the refining reaction at high refining rates. Continuous addition of ore in small quantities only permits carbon burn-off rates of about 0.3-0.5% C/h, which entails long heat times when large proportions of pig iron are used, together with a considerable drop in hourly throughput as compared with 100% solid charges. Charging large amounts of ore on to the furnace hearth or mixed with the solid charge materials can, as experience has shown, lead to non-uniform reactions associated with spontaneous ejection of slag and steel as soon as the bath has reached a high temperature.

Operating Technique

When scrap and liquid pig iron are charged together, the arcs proceeding from the electrodes melt vertical cylindrical or crater-shaped channels into the scrap projecting up from the liquid metal bath surface and tend to make direct contact with the pig iron covering the furnace hearth. This takes place faster when there is less scrap. The channels widen gradually under the influence of the arcs and can be considered for a limited period as self-contained crucibles or melting vessels, their walls being formed of scrap and their contents of liquid pig iron. As soon as the arcs reach the liquid pig-iron bath surface they try to form a closed circuit with the latter. Thus the heat produced is concentrated in a very confined space and is transmitted to the liquid metal. If the ore required to refine the pig iron is now added mainly in the immediate vicinity of the arcs playing on the bath, it enters into rapid and violent reaction with the accompanying elements contained in the pig iron. At the same time this reaction (at first locally confined) between the ore and the pig-iron carbon produces a pronounced effervescence in the slag formed; the arcs are completely covered and screened by it and subsequent rapid melting of the scrap is delayed. A considerable proportion of the heat produced by the arcs is expended in reduction of the ore by the accompanying elements in the pig iron. Further melting of scrap can only take place to a limited extent by the direct arc action and is mainly due to gradual heating from the already molten part of the charge in which the scrap is immersed. In this way not only is the reaction centre, where the energy input is high, screened off so that the furnace walls cannot be directly affected by radiation from the arcs, but also the scrap still to be melted acts as an independent temperature regulator. Under these conditions the carbon burn-off reaction can be controlled by direct adjustment of the energy input.

Ore can be charged into this gradually widening crucible either by direct charging or by suitable mixing in the solid charge, so that the ore is mainly contained in the vicinity of the crucibles as they form and is exposed to the direct arc action at an early stage. The lime required can be handled in the same way, so as to ensure early slag formation.

When, after a certain time, the three separate crucibles first formed by the arcs come to break down, the ore already added will have largely dissolved in the slag and much of it will have already been reduced. The bath continues to boil uniformly and the ferrous oxide content of the slag to fall correspondingly until the required initial carbon content is reached. By estimating the ore quantity as closely as possible, with reference to the pig-iron analysis, scrap composition, and the extent to which the scrap is oxidized, the desired initial carbon content can be achieved with sufficient accuracy. The heat is finished in any required manner, as with ordinary scrap heats. When high-phosphorus pig iron is charged, the phosphate slag is removed at a higher carbon content and refining completed

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under a second low-phosphorus slag. When low-phosphorus pig iron is charged, the amount of ore can be estimated so that the initial carbon content is only a few points below the required final content and only a short time is needed to finish the heat.

Table I gives the time-table for the heat, with the corresponding bath and slag analyses. It must be pointed out in connection with this table, that because of the refining process being repeatedly interrupted and because of the heat losses due to removing the roof, the melting time was considerably increased.

Time, min	Operation/ Condition	Steel C, %	Steel P, %	Slag P_2O_5, %	Slag Fe, %
0	Switch-on	3.50	1.770		
50	Remove roof sample 1	2.28	0.570	16.75	17.90
85	" " 2	1.58	0.275	14.47	10.82
115	" " 3	0.92	0.030	15.00	18.30
140	Scrap all melted sample 4	0.68	0.025	14.81	17.30
150	Sample 5	0.58	0.035	13.77	13.38

Table I. Changes in bath and slag composition during refining, with about 50% liquid high-phosphorus pig iron in the charge.

Furnace Data

Table II gives the most important characteristics of the arc furnaces.

Characteristic	40-Ton Furnace	12-Ton Furnace
Electrode control	electric-hydraulic	electric-hydraulic
Nominal size, tons	30	12
Charge weight, tons	38-42	13-15
Transformer rating, kVA	18,000	3,500
Primary voltage, v	45,000	3,000
Secondary voltage, v	370/129	200/81
Electrode material	Graphite	Graphite
Electrode diameter, mm	500	350
Secondary current per electrode, A	27,000	10,100
Method of charging	pan	pan
Inside dia. of casing, mm	5,200	3,200
Electrode pitch dia., mm	1,600	1,250

Table II. Characteristics of arc furnaces used.

Material Data

Typical pig iron compositions are contained in Table III. The temperature of the pig iron on charging into the furnace was about 1250-1300°C.

Operational Results

The overall melting time for a heat, reckoned from tap to tap, can be divided into three stages, the durations of which are influenced by different factors:

(1) *Charging and intermediate time.*
(2) *Melt-down time.*
(3) *Time for finishing the heat.*

In comparing different arc furnace melting techniques, i.e., in this case in comparing the all-scrap technique with the pig iron plus ore technique, one must first consider the melt-down times, the melting rates, and the corresponding energy consumption associated therewith. In the following, the times up to taking the first sample are compared for the two methods of working (the all-scrap technique and the pig iron plus ore technique), the first sample being taken with the melts in roughly the same condition. In the pig iron plus ore technique, the melt-down time includes melting the scrap and refining the pig iron. The finishing of the heat should then require about the same time for similar steel qualities, so long as the preceding refining period in the pig iron plus ore technique exerts no decisive influence on the further metallurgical progress of the melt until it is tapped.

Table III in addition to giving data on the charge, the pig-iron composition, and the steel composition at the first sampling, gives the melt-down time (from switch-on to first sample), the melting rate calculated from the latter, and the corresponding energy consumption for charges with around 50% liquid pig iron, against the results for 100% scrap charges.

Of the heats melted in the 12-ton arc furnace (groups 1-3), special mention should be made of those with high-phosphorus pig iron, since low-phosphorus pig iron was only used in a few tests. The phosphorus content of the pig iron was 1.84%, as the average of 173 heats made in the course of production; against this the first steel samples showed 0.060%P with an average carbon content of 0.42%. Despite the considerable energy consumption in dephosphorization, the melting load (7.50 tons/h) is about 32% higher than for the all-scrap heats quoted for comparison. It should also be noted that the scrap heats were subject to special observation as test heats, and the results achieved were thus even better than could be expected in the course of normal production. The energy consumption to melt-down at 384kWh/ton, is 23% lower than with an all-scrap charge. The three heats with low-phosphorus pig iron in the charge show even better results.

In the tabulated results obtained in the 40-ton arc furnace groups (4-7), the average values for 82 successive

Group No.	No. of Heats	Furnace	Metal charge, Kg	Pig-iron proportion, %	Pig-iron Analysis, % C	Si	Mn	P	S	Steel Analysis, % (1st Sample) C	Mn	P	S	Switch-on to 1st Sample: Time Min	Output rate, t/hr.	Energy kWh/t
1	10	12 t	11,515	0	—	—	—	—	—	0.34	0.26	0.047	0.046	125	5.6	474
2	3	12 t	14,740	51.5 low-phosphorus	3.92	1.44	0.87	0.085	0.035	0.57	0.11	0.057	0.043	110	8.1	340
3	173	12 t	13,880	48.1 high-phosphorus	3.56	0.55	0.64	1.840	0.041	0.42	0.19	0.060	0.028	112	7.5	384
4	155	40 t	40,900	0	—	—	—	—	—	0.31	0.33	0.049	0.061	97	25.2	456
5	82	40 t	40,656	47.1 low-phosphorus	3.44	0.69	0.50	0.111	0.051	0.38	0.14	0.036	0.052	70	34.7	328
6	41	40 t	40,257	46.8 high-phosphorus	3.33	0.79	0.38	1.370	0.055	0.32	0.16	0.037	0.040	74	33.1	348
7	12	40 t	36,900	49.4 low-phosphorus	3.63	0.72	0.63	0.125	0.047	0.22	0.18	0.021	0.041	54	41.0	344

t = tons charged

Table III. Charge data up to first sampling, 12- and 40-ton electric arc furnaces.

Melting charge composition	Charge wt., tons	Hearth Dia., mm	Transformer rating, kVA	Maximum melt-down voltage, V	Melting rate, ton/hr	Remarks
100% solid	12.5	3,800	5,000	220	6.6	E. Pakulla
100% solid	11.5	3,200	3,500	200	5.6	von Roll
50% liquid pig-iron low P	14.7	3,200	3,500	200	8.1	von Roll
50% liquid pig-iron high P	13.9	3,200	3,500	200	7.5	von Roll
100% solid	35.0	5,200	9,000	270	11.5	E. Pakulla
100% solid	73.0	5,700	15,000	340	17.9	E. Pakulla
100% solid	40.9	5,200	18,000	370	25.2	von Roll
50% liquid pig-iron low P	36.9	5,200	18,000	370	41.0	von Roll
50% liquid pig-iron high P	40.3	5,200	18,000	370	33.1	von Roll

Table IV. Furnace data, charging with 100% solid charge, and 50% liquid pig-iron charge.

heats with low-phosphorus and 41 with high-phosphorus pig iron are again compared with results from all-scrap operation. The carbon and phosphorus contents of the first samples varied little. Against the 100% scrap heats, a reduction of about 29% in energy consumption is obtained when charging 50% liquid low-phosphorus pig iron and about 23% with high-phosphorus pig iron. The melting rate is correspondingly 37% and 32% higher.

Table IV gives the hearth diameters, charge weights, transformer capacities, and maximum melt-down voltage for the arc furnaces at Gerlafingen, and the melting rates achieved with 100% solid charge and with 50% liquid pig-iron charge, compared with the values published by Pakulla for various arc furnaces. Bearing in mind the differences in charge weight and the different transformer capacities, the melting rates achieved for 100% solid charges in the 12-ton arc furnace are more or less comparable. The decisive influence of transformer capacity can be seen in the example of the 40-ton furnace. With a transformer capacity of 18,000kVA and a charge weight of about 41 tons, a melting rate of 25.2 tons/h was achieved at Gerlafingen on 100% scrap charges, whereas Pakulla quotes only 17.9 tons/h for a furnace with larger hearth diameter and a 73-ton charge, but with a lower transformer rating of 15,000kVA. Thus the melting rates reached with 50% liquid pig iron in the 40-ton furnace (18,000kVA), i.e., 41.0 tons/h for low-phosphorus pig iron and 33.1 tons/h with high-phosphorus, are as much as 138% and 86% higher respectively than quoted by Pakulla for the 70-ton furnace equipped with a less powerful transformer (15,000kVA) working on all scrap.

Figures 1 and 2 show the course of heats in the 40-ton arc furnace charged respectively with low- and high-phosphorus pig iron. The initial compositions plotted on the vertical axis refer to the average charge compositions (pig iron and scrap). The carbon burn-off curves were drawn to approximate the actual course of refining. Tables V and VI give the material balances for the two heats shown in Figs. 1 and 2.

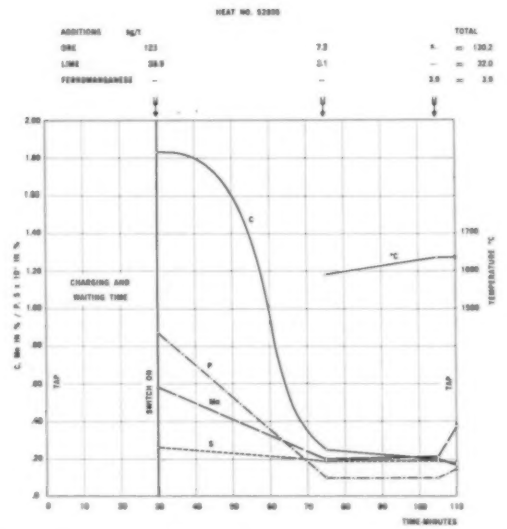

Figure 1. Curves for a heat in the 40-ton arc furnace, charged with 50% low-phosphorus liquid pig iron.

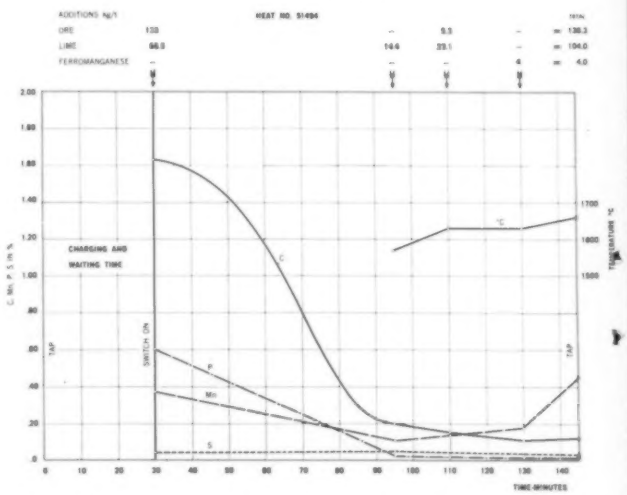

Figure 2. Curves for a heat in the 40-ton arc furnace, charged with 50% high-phosphorus liquid pig iron.

	Total charge, kg	Molten yield, kg/ton	Metal charged (scrap + pig), %	Total metal content (scrap + pig + Fe from ore + FeMn), %
Charge				
Scrap	17,000	491.5	50.0	45.7
Liquid pig iron	17,000	491.5	50.0	45.7
Total metal charged	34,000	983.0	100.0	91.4
Fe from 4,500 kg ore (68% Fe)	3,065	88.5	9.0	8.2
Ferromanganese	135	3.9	0.4	0.4
Total metal content of charge	37,200	1,075.4	109.4	100.0
Lime	1,110	32.0	3.3	3.0
Yield				
Molten steel	34,600	1,000.0	101.8	93.0
Burn-off	2,600	75.4	7.6	7.0
Total	37,200	1,075.4	109.4	100.0

Table V. Charge data for a 40-ton arc furnace heat with 50% liquid low-P pig iron in the charge (Heat No. 52895).

	Total charge, kg	Molten yield, kg/ton	Metal charged (scrap + pig), %	Total metal content (scrap + pig + Fe from ore + FeMn), %
Charge				
Scrap	19,500	518.0	52.3	47.7
Liquid pig iron	17,800	474.0	47.7	43.6
Total metal charged	37,300	992.0	100.0	91.3
Fe from 5200 kg ore (65% Fe)	3,370	89.6	9.0	8.3
Ferromanganese	150	4.0	0.4	0.4
Total metal content of charge	40,820	1,085.6	109.4	100.0
Lime	3,910	104.0	10.5	9.6
Yield				
Molten steel	37,600	1,000.0	100.8	92.0
Burn-off	3,220	85.6	8.6	8.0
Total	40,820	1,085.6	109.4	100.0

Table VI. Charge data for a 40-ton arc furnace heat with 50% liquid high-P pig iron in the charge (Heat No. 51494).

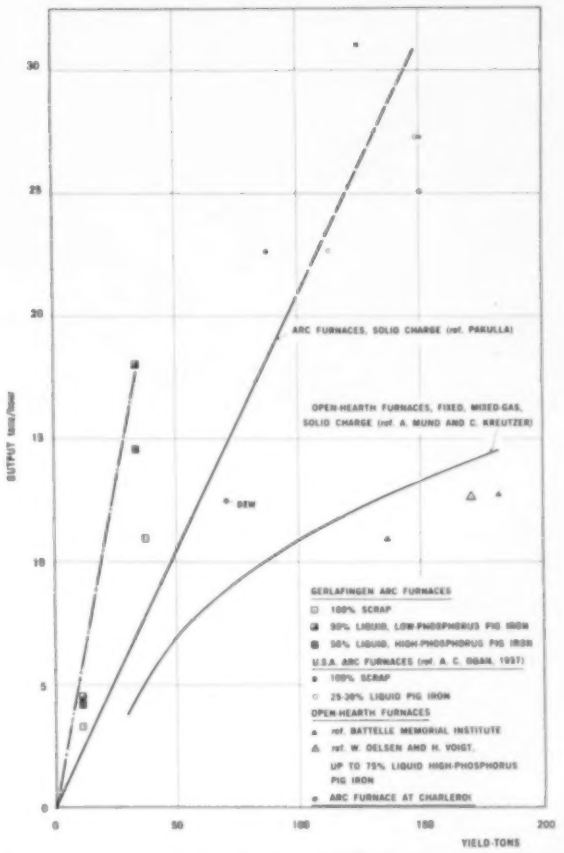
OUTPUT tons/hour
YIELD-TONS
ARC FURNACES, SOLID CHARGE (ref. PAKULLA)
OPEN-HEARTH FURNACES, FIXED, MIXED-GAS, SOLID CHARGE (ref. A. MUND AND C. KREUTZER)
DEW
GERLAFINGEN ARC FURNACES
100% SCRAP
90% LIQUID, LOW-PHOSPHORUS PIG IRON
90% LIQUID, HIGH-PHOSPHORUS PIG IRON
U.S.A. ARC FURNACES (ref. A. C. OBAN, 1957)
100% SCRAP
25-30% LIQUID PIG IRON
OPEN-HEARTH FURNACES
ref. BATTELLE MEMORIAL INSTITUTE
ref. W. OELSEN AND H. VOIGT.
UP TO 75% LIQUID HIGH-PHOSPHORUS PIG IRON
ARC FURNACE AT CHARLEROI

Fig. 3. Hourly outputs for arc furnaces charging 100% scrap and large proportions of liquid pig iron, compared with fixed O H furnaces.

The decisive factor in the increased output for charges with high proportions of liquid pig iron is mainly the shortened melt-down time to the first sample. The finishing of the heat proceeds in the normal manner for the arc furnace, regardless of the type of charge. When liquid pig iron is charged, lively boiling takes place during the melt-down, associated with extensive dephosphorization and desulphurization, so that the finishing time can also be curtailed without deleterious effects on steel quality.

With this increase in output is associated a notable reduction in energy consumption, namely about 17% for heats with high-phosphorus pig iron in the charge and about 21% in the case of low-phosphorus pig iron. These energy consumption figures, like those for hourly output, refer to the molten steel yield.

Fig. 3 shows the hourly outputs for arc and O H furnaces, as a function of furnace size (yield in tons). In this figure the values published by Pakulla, based on output figures from arc furnaces at Deutsche Edelstahlwerke and on data from the Battelle Memorial Institute Report, are amplified by our own test results and by more recent data on large arc furnaces and O H furnaces operating on the pig iron plus ore technique. The hourly outputs for the 40-ton arc furnace operating with about 50% liquid pig iron are higher than for the 200-ton O H furnace and roughly correspond to the good results on 70-ton arc furnaces operating on 100% solid charge.

The consumption of *refining ore* depends largely on the pig iron composition, the desired final carbon content, and (by no means least) the oxygen content of the ore itself. If a rich hematite ore is used, one can estimate at about 220-290 kg ore per ton of pig iron. Using magnetite ore, the ore consumption is correspondingly higher. The degree of oxidation of the scrap can greatly influence the ore consumption.

The iron pickup from the ore depends on the proportion of pig iron in the charge and the ore required per ton of pig iron. With pig-iron proportions of about 50-70%, the iron pickup was between 8 and 12% of the weight of metal charged.

The yield of metal was closely observed during the series of tests. Taking into account the iron contained in the ore, the molten metal yield averaged between 92 and 94%. Referred to the metallic charge alone (pig iron and scrap) this gave a yield of about 101-103%, corresponding to an iron pickup from the ore of about 9%.

The lime consumption is greatly influenced by the pig iron composition. Melts with pig iron low in phosphorus and silicon content under 1.0% required an average 32 kg/ton of steel. When the pig iron contained more silicon and more desulphurization was required, the lime requirement rose to over 50 kg/ton of steel.

All data in this article are expressed in metric units.

Metallurgical Considerations

Carbon

The carbon burn-off rate, which has a decisive influence on the duration of the heat, is determined by the quantity of oxygen introduced per unit of time. However, since the reaction between the ore and the carbon is strongly endothermic, the carbon burn-off rate in the presence of sufficient ore becomes a function of the electrical energy supplied per unit of time.

When, as in the examples quoted, the refining time is kept below 1hr. with about 50% liquid pig iron in the charge, the mean carbon burn-off rate can be reckoned at about 2% C/h. Considering only the pig iron in the charge, this corresponds to a mean carbon burn-off rate, for the pig iron of about 3%C/h. In Figs. 1 and 2 it was shown that carbon burn-off does not proceed uniformly during the refining period. In the first 10-15 min it is relatively low, reaching its maximum during the next 25-30 min and falling off again towards the end of refining. Roughly 75% of the carbon is oxidized within about 25 min. In this period one must assume a mean carbon burn-off rate of about 3%C/h, referred to the total charge, and a true rate of about 6%C/h for the pig iron.

When carbon is oxidized, considerable volumes of carbon monoxide are formed. For the types of charge described, and with the carbon burn-off rate held high, it was necessary to reckon with the evolution of about 0.5 m^3/s (NTP) of CO during the main refining period. The gas issuing from the furnace during this period contained about 70-80% CO.

Phosphorus

When high-phosphorus pig iron is charged in the arc furnace, dephosphorization becomes of decisive importance. An example of dephosphorization, in comparison to that of carbon burn-off, has already been given in the discussion of the principles underlying the technique. Although the pig iron contained 1.77%P, at 0.92%C in the bath, dephosphorization had already proceeded to 0.030%, with the slag loaded up to 15%P_2O_5. Thus under these working conditions, dephosphorization can be made largely to precede carbon burn-off.

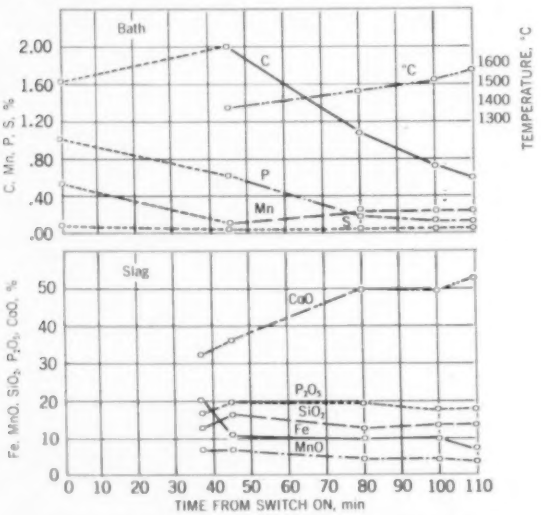

Fig. 4. Refining in 12-ton arc furnace with about 50% liquid high-phosphorus pig iron in the charge. Charge No. 54988.

Figure 4 shows the burn-off of the accompanying elements in the pig iron, in detail, together with the changes in slag composition during the refining period. With a charge containing about 50% pig iron of phosphorus content 1.96%, the amount of lime used was 13.7% of the weight of pig iron. At the end of the refining period the slag contained 17.40% P_2O_5 and 6.41%Fe, and the bath 0.58%C and 0.100%P. The bath temperature was 1565°C.

Table III gives the mean compositions of the pig iron and of the first steel samples for 173 heats in the 12-ton furnace and 41 heats in the 40-ton furnace. When these are compared with corresponding samples for heats made with low-phosphorus pig iron and with 100% scrap, it can be seen that, in spite of the high phosphorus content of the pig iron, that of the steel is at about the same low level. Bearing in mind the short refining period and the low energy consumption, this result is very satisfactory.

With increasing free lime content or decreasing P_2O_5 content in the slag, definitely lower phosphorus contents were found in the steel. Better dephosphorization was obtainable in the 40-ton arc furnace for comparable free lime contents in the slag. Apparently the higher specific transformer capacity has a favorable influence here, causing more intense and more uniform reaction between slag and bath.

The slags rich in P_2O_5 were normally removed after the first sample to eliminate the remaining carbon after replacing with a second highly basic slag and to finish the heat in the normal way. This also facilitates further dephosphorization down to very low levels. The composition of the first phosphorus-rich slag suggests that it may find use as a fertilizer. Investigations of the citric acid solubility of these slags are in progress.

Figure 5 shows the frequency distribution curve for the final phosphorus contents reached in the finished steel (tap samples), for 144 successive heats. In spite of the high phosphorus content in the pig iron, namely 1.8%, over 75% of all heats contained less than 0.030%P. In the few heats with higher phosphorus contents the slag was not removed adequately, so that the increased P_2O_5 in the finishing slag led to ready phosphorus reversion as the temperature was raised. In the 40-ton furnace similar results were attained.

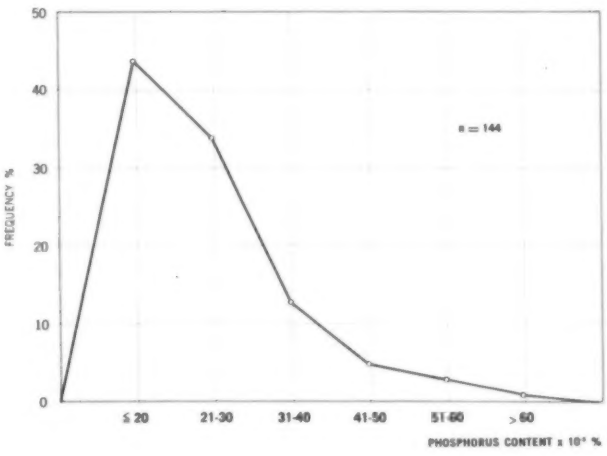

Fig. 5. Frequency distribution curve of phosphorus content of the finished steel from 144 heats under continuous production conditions with about 50% liquid high-phosphorus pig iron.

Sulphur

Desulphurization in the arc furnace causes no particular problems. When high-phosphorus pig iron was charged, however, desulphurization during the refining period was found to be clearly superior to the case when low-phosphorus pig iron was charged. The samples come from three test series with high-phosphorus pig iron and different amounts of lime in the charge. The differences in mean free lime content of the slags compare as follows:

Test series	*Furnace capacity, tons*	*Free lime content, %(CaO)'*
A	12	23.55
B	12	17.90
C	40	12.98

In group A, with the highest mean free lime content, were found the highest partition coefficients and the lowest sulphur contents for the steel.

Using highly basic finishing slags practically any sulphur limit requirement can be met in the arc furnace. In the majority of the heats it was possible to get below 0.020%S, despite the relatively high sulphur contents of pig iron and scrap. In the 40-ton arc furnace, a considerably lower slag basicity was used experimentally, so that somewhat higher sulphur contents had to be expected in the steel.

Nitrogen

In about 70% of the heats, values of 0.004%N or less were obtained. Tests carried out later have shown that values of 0.002-0.003%N can be maintained for unkilled mild steels, and 0.004%N for killed steels.

Experiments on Direct Steelmaking by Additional Smelting of Ore Fines with Coke Fines

From the point of view of material costs, the gain in iron from the ore can have considerable economic importance. The iron in the ore is converted directly into steel ready to pour. Durrer pointed out years ago that the pig iron plus ore process is the only one used on a truly industrial scale in which iron in the ore is converted in one operation to finished steel.

Following Durrer's line of thought, further tests were carried out in which more ore was added to the charge than required to refine the pig iron, and the extra ore reduced using additional solid carbon, e.g., coke fines, in the arc furnace.

In tests in the 12-ton and 40-ton furnaces it was possible in this way to obtain an iron gain in the form of finished steel, amounting to more than one-third of the original metallic charge. Thus the molten-steel yield in terms of pig iron and scrap charged could be raised to more than 130%.

As an example of the economic possibilities of such a technique, data are given on a heat made in the 40-ton furnace. Table VII shows the material balance for a heat in which additional iron to the amount of 23.1% of the weight of metal (pig iron and scrap) charged was obtained from ore and converted directly to steel. The yield in terms of the total metal content of the charge was 91.4%; it can thus be assumed that practically all the ore had been reduced and only the natural losses have occurred.

	Total charge, kg	Metal yield, kg/ton	Pig iron + scrap charged, %	Total metal content (scrap + pig + Fe from ore + FeMn), %
Charge				
Scrap	15,500	445.0	50.3	40.6
Liquid pig iron	15,300	438.0	49.7	40.1
Total metal charged	30,800	883.0	100.0	80.7
Fe from 10,000 kg ore (68% Fe)	7,130	204.4	23.1	18.7
Ferromanganese	230	6.6	0.8	0.6
Total metal content of charge	38,160	1,094.0	123.9	100.0
Lime	1,400	40.2	4.6	3.7
Coke fines	1,900	54.5	6.2	5.0
Yield				
Molten steel	34,880	1,000.0	113.3	91.4
Burn-off	3,280	94.0	10.6	8.6
Total	38,160	1,094.0	123.9	100.0

Table VII. Material balance for a 40-ton arc furnace heat with additional smelting of ore fines and coke fines, Heat No. 52597, 23.1% Fe gain from ore.

In spite of the relatively extensive reduction required, the entire melting time from tap to tap was only 160 min. In comparison with the 100% scrap technique, roughly the same hourly output was attained despite the extensive reduction, but the energy consumption was increased by about 15-20%.

Since in this type of heat three processes, namely scrap melting, pig iron refining, and ore reduction by the additional solid carbon charged, are taking place side by side, it is difficult to find the true energy consumption for these three heat-consuming processes. An estimate of the heat consumed in melting the scrap and in refining the pig iron, on the basis of known consumption figures, suggests that one can reckon on requiring less than 2,000kWh/ton for the energy to convert the ore directly to steel; in other words, less energy is needed than in the production of pig iron in the electric smelting furnace.

Input records for the 40-ton furnace show that with a charge consisting entirely of scrap, the frequent arc extinction leads to pronounced variations in input, whereas both when liquid pig iron is charged, and with additional reduction, the energy input is very steady and the furnace operates completely quietly.

Summary and Conclusions

Full-scale tests have been carried out in 12-ton and 40-ton arc furnaces in which the charges contained large proportions of liquid pig iron and ore was used as refining agent. The principle of the technique has been discussed and the progress of melting described and illustrated. Tests have shown that the refining reaction can be controlled despite the high refining rate.

Under continuous production conditions, both low-phosphorus and high-phosphorus qualities of pig iron have been used in the charge. In both cases a considerable increase in the hourly output together with a reduction in energy consumption have been recorded. In the 40-ton arc furnace it was possible to reach hourly outputs of up to about 15 tons/h with charges containing about 50% liquid high-phosphorus pig iron, and exceeding 18 tons/h with low-phosphorus, corresponding to an increase in output of 30% and 60% respectively, as against normal operation of the furnaces with 100% scrap charges. The energy consumption for the majority of heats was less than 500kWh/ton of liquid steel.

Rich ore fines were particularly well suited as refining ores. With about 50% pig iron in the charge, one could expect a gain of about 8-10% of the charge weight from the ore. The metallic yield, referred to the metallic charge of pig iron and scrap, thus rose to more than 100%. The life of the furnace refractories was roughly as good as with 100% scrap charges. Durability figures of 137-163 heats were obtained for the walls and over 100 heats for the roof. The electrode consumption was about 5 kg/ton. High-phosphorus pig iron could be dephosphorized to low levels without notably extending the refining time. The P_2O_5 contents of better than 15% reached in the slag suggest that it can be used as a fertilizer.

Finally, it is shown in one example that the proportion of steel obtained directly from ore can be considerably increased by the additional reduction of ore fines with coke fines. Within the limits of the tests so far carried out, up to one-third of the weight of steel can be obtained directly from ore. The majority of tests were carried out with about 50% pig iron in the charge. When the pig-iron content was raised to about 70% roughly the same results were obtained.

The problem which originally formed the basis of this work, namely the economic conversion of high-phosphorus pig iron to steel in the arc furnace, can be regarded as solved, at least as far as conditions in Switzerland are concerned. With the increasing expansion of electric steel-making, the problem of refining pig iron in the arc furnace has recently gained steadily in importance in other countries also. The present results will therefore be of wider interest than to the Swiss industry alone. If the authors' views are correct, arc furnaces will gain in competitive importance by the possibility of handling pig iron to the same extent as in O H furnaces.

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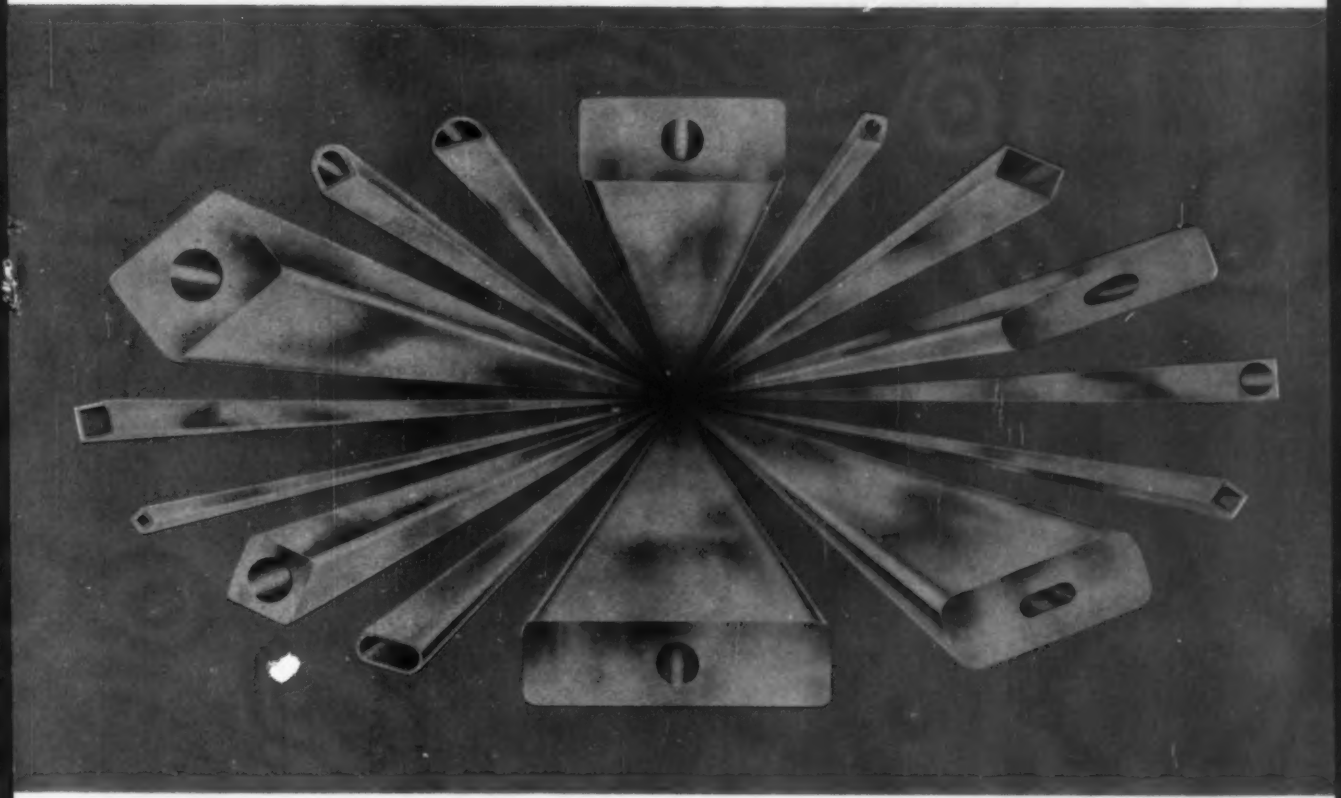

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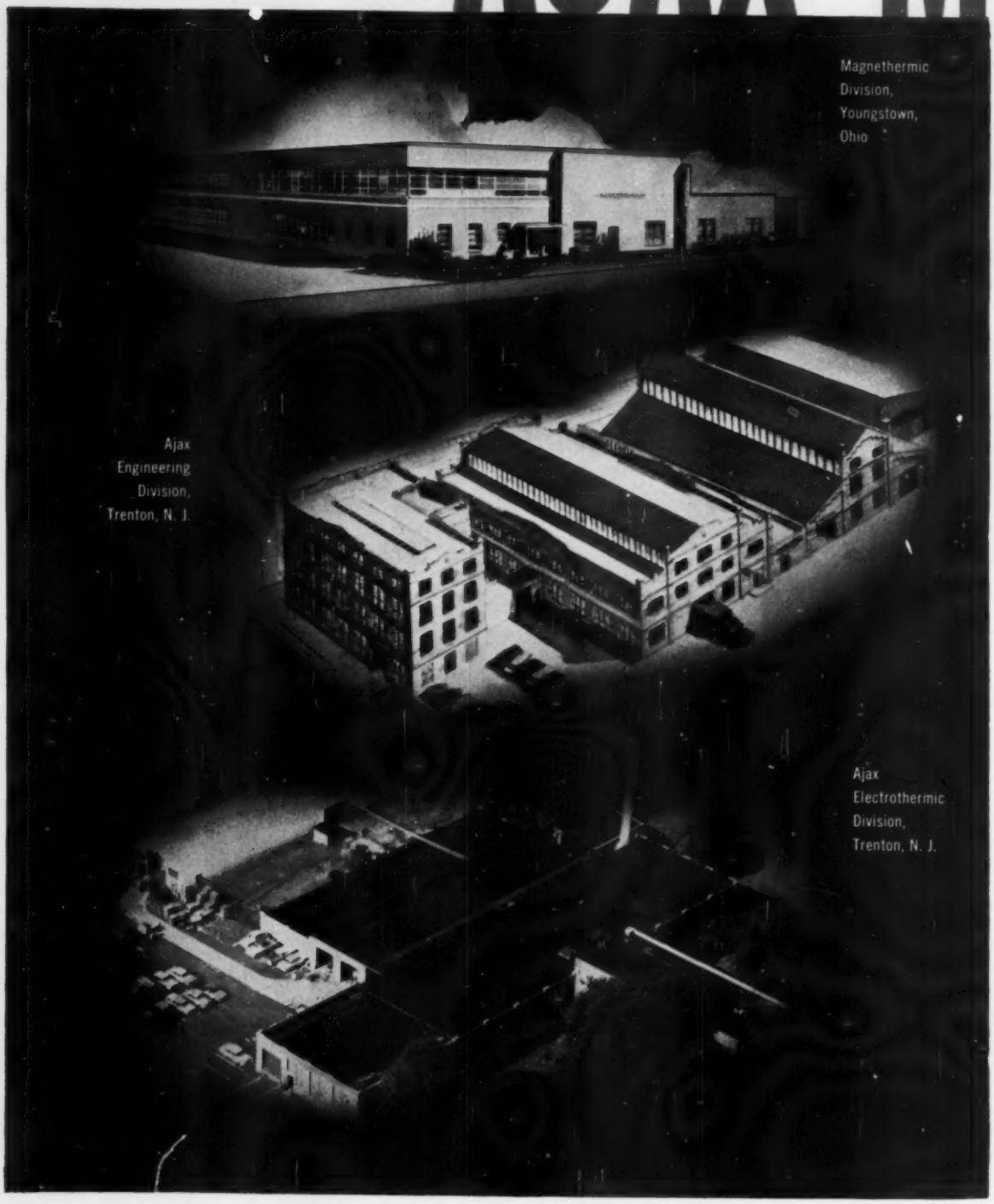

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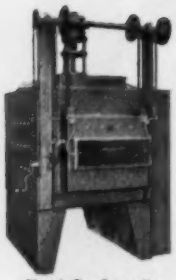

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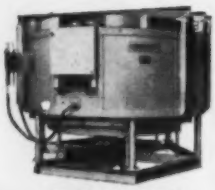

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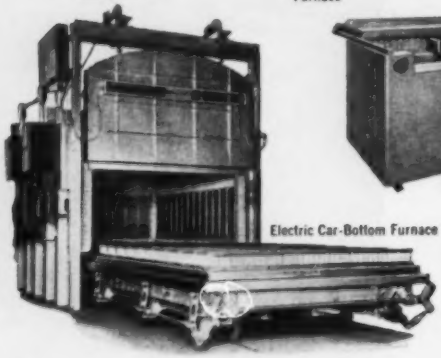
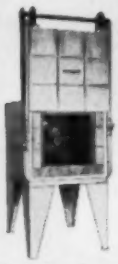


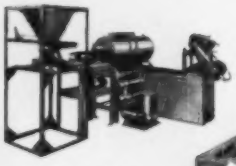
Electric Car-Bottom Furnace



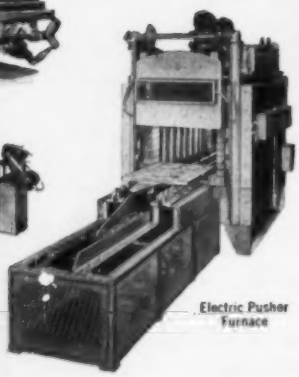
Electric Draw Furnace

Gas-Fired Endothermic Gas Generator

Gas-Fired Salt Pot Furnace



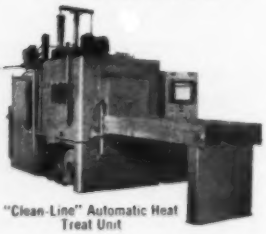
Electric Shaker Hearth Furnace



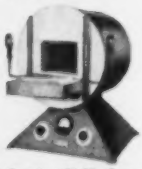
Electric Pusher Furnace

Gas-Fired Airdraw Furnace

Electric Vertical Retort Furnace

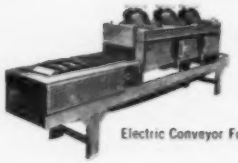


"Clean-Line" Automatic Heat Treat Unit

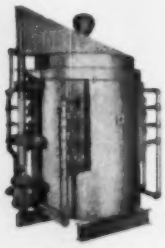


Laboratory Muffle Furnace

Combustion Tube Furnace



Electric Conveyor Furnace



Gas-Fired Pit Furnace

What's going on at

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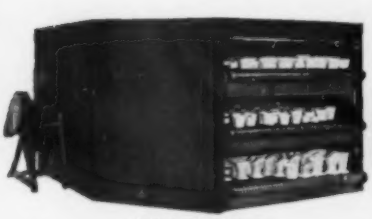
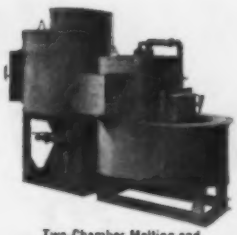
Industrial Furnaces and Ovens, Electric and Fuel • Laboratory Furnaces • Dry Type Transformers • Constant Current Regulators

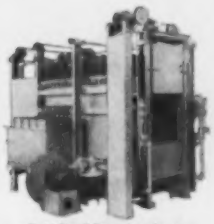


Multi-Level Belt Dryer

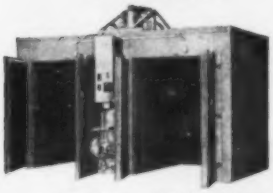
Monorail Conveyor Oven



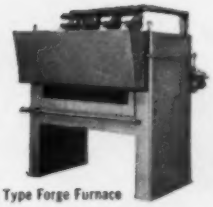
Two-Chamber Melting and Holding Furnace



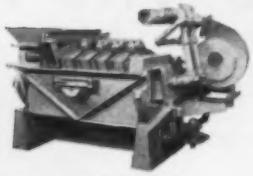
Fuel-Fired Reverberatory Furnace



Two-Chamber, Rack-Loaded Oven



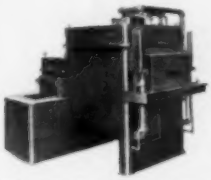
Slot Type Forge Furnace



Cradle-Type Melting Furnace

Reverberatory Aluminum Melting Furnace

Gas-Fired Tray Loaded Oven

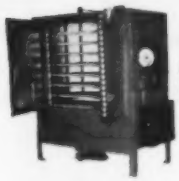


Double Chamber Dry Hearth Melting and Holding Furnace

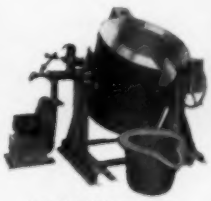
Magnesium Melting and Holding Furnace

Gas-Fired Barrel Melting Furnace

Electric Resistance Holding Furnace

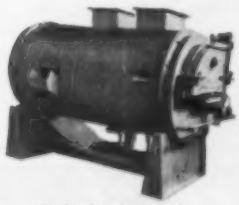


Electric Tray Loaded Oven



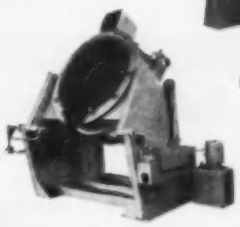
Iron Pot Melting Furnace

Double Chamber Aluminum Melting and Holding Furnace



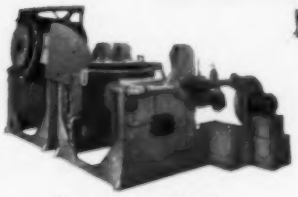
Double Chamber Barrel Furnace

Stationary Crucible Melting Furnace



Hydraulic Tilt Iron Pot Furnace

Electric Crucible Holding Furnace



Mechanically Tilted Crucible Melting Furnace

Gas-Fired Crucible Melting and Holding Furnace

It was planned for years . . . a big, brand new plant with the latest production facilities . . . the acquisition of several heating equipment companies . . . and suddenly, Hevi-Duty offers the largest, most complete line of electric and fuel fired furnaces and ovens in the industry. Shown here are representative units available.

Write for complete details. Perhaps that expensive "custom-built model" you need is a standard item or a simple adaptation from the *big* Hevi-Duty line.

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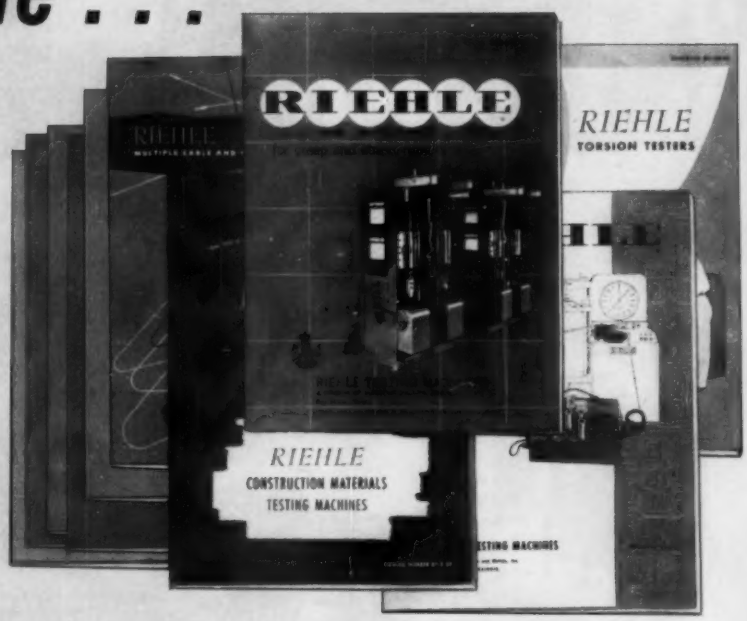
A DIVISION OF BPC — BASIC PRODUCTS CORPORATION

HEVI-DUTY ELECTRIC COMPANY, MILWAUKEE 1, WISCONSIN

UPDATE

your Riehle Testing Machine reference file . . .

To help you expand your testing machine reference file, several additional* bulletins recently have been included in the Riehle collection of technical information. Simply check the list below, clip it to your letterhead, and we'll promptly send the literature you request. There is no obligation.



Check your wants

- ☐ *The Charpy Impact Machine and Procedure for Inspecting and Testing Charpy V-Notch Impact Specimens
- ☐ Universal Hydraulic Testing Machines and Accessories
- ☐ Universal Screw Power Testing Machines and Accessories
- ☐ Construction Materials Testing Machines and Accessories
- ☐ Torsion Testing Machines
- ☐ *Glossary of Terms Representing Mechanical Properties and Tests
- ☐ Creep and Stress-Rupture Testing Machines
- ☐ Losenhausen Fatigue Testing Machines
- ☐ *Newly Introduced Fatigue Testing Machines
- ☐ Riehle Electro-Balanced Indicator Unit
- ☐ Brinell Hardness Testers
- ☐ Vickers Hardness Testers
- ☐ Portable Hardness Testers
- ☐ *Hardness Conversion Chart for Hardened Steels
- ☐ Cable and Wire Testers
- ☐ Horizontal Tensile Testing Machines
- ☐ *An Axial Loading Creep Machine
- ☐ Impact Testing Machines
- ☐ Testing Machines Guide
- ☐ Riehle Recorder and Accessories
- ☐ Handsome wall plaque, reading: "One Test is Worth a Thousand Expert Opinions." ™

Riehle® TESTING MACHINES

A DIVISION OF

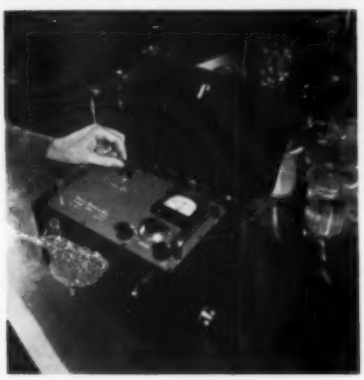
American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

APPLICATION and EQUIPMENT new products

Cleanliness Tester

A new cleanliness tester that makes it possible to assign numerical values to surface cleanliness where non-bonded soils are involved has been announced by Branson Ultrasonic Corp. The tester has a linear scale from 0 to 1000 with 1000 indicating absolute cleanliness. Accuracy of one part in a thousand is made possible by a ten-turn potentiometer in the balancing circuit. Testing involves the following two steps: (1) Soil is removed from the surface under test with transparent, pressure-sensitive tape that is then affixed to a microscope slide. (2) Optical density of the

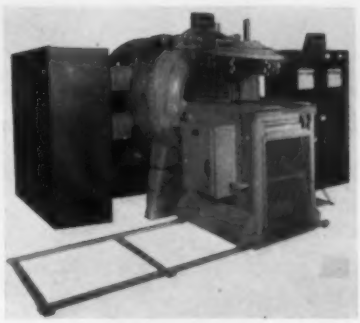


composite (tape, soil, and slide) is measured by the tester, which is actually a densitometer designed for that purpose. The unit measures 12 by 14 by 8 in. and weighs 18¼ lb. Power drawn is 50 w. at 100 v., 60 cycles.

For further information circle No. 755 on literature request card, page 48-D.

High-Vacuum Furnace

An automatic high-vacuum furnace with a workspace of 24 by 36 by 12 in., operating at a pressure of 1 mm. Hg. and a temperature of 2275° F., has been announced by Ipsen Industries, Inc. This heat treating unit is adaptable for copper and for nickel brazing of flat stainless assemblies that are heated from above and below. Other uses include hardening, tempering, drawing and annealing refractory metals, reactive metals, stainless and



special alloy steels. The furnace is charged horizontally and has a roller hearth. The charging door operates airdraulically and has a 3-in. sight glass. The vacuum system consists of a 100-cfm. mechanical pump and a 10-in. diam. vapor diffusion pump.

For further information circle No. 756 on literature request card, page 48-D.

Metallizing Wire

General Electric Co. has announced stranded tungsten wire with an aluminum case for vacuum metallizing. The new wire becomes an open-strand design the first time it is flashed in use. As the aluminum core vaporizes and disappears in the first flash of the metallizing process, space is left between the tungsten strands of the coil. This increases tungsten surface area over tightly-twisted tungsten strands. The tungsten wire is long grained for longer life and extra strength.

For further information circle No. 757 on literature request card, page 48-D.

Ultrasonic Cleaner

A new ultrasonic cleaning unit that can handle two different jobs at the same time in small parts cleaning, laboratory processing and investiga-

tion of various ultrasonic phenomena has been announced by the Narda Ultrasonics Corp. This new Son-Blaster agitates the contents of two 400-ml. glass beakers. It is possible to wash and rinse parts simultaneously, use two different solutions at the same time, use any chemical, acid, or alkali solvent in glass beakers, or use the stainless steel tank without beakers. Equipment includes an ultrasonic generator, a transducerized ultrasonic tank and two glass beakers.

For further information circle No. 758 on literature request card, page 48-D.

Seamless Tube

A new integral finned low-carbon and alloy seamless steel tube has been announced by Michigan Seamless Tube Co. New extruding equipment has made it possible to produce integral finned seamless steel tube for use in shell and tube heat exchangers. The tube is furnished with plain ends for rolling into tube sheets with the out-

side diameter of the plain end and the finned portion being the same. Tube diameters from ½ to 1 in. can be furnished with wall thickness of 0.035 in. and heavier. Bi-metal finned tubing using either carbon steel or alloy steel is available.

For further information circle No. 759 on literature request card, page 48-D.

Microhardness Tester

A Tukon tester designed for shallow-indentation hardness testing of hot metals or metal components that have been exposed to radioactive or nuclear energy contamination has been announced by the Wilson Mechanical Instrument Div., American Chain & Cable Co. Because of the nature of the work being performed, all control functions are mechanically operated and are extended out through the wall

When Bell & Howell switched to Nialk Trichlorethylene with **psp**—permanent staying power, it extended clean-outs to a full three months.

How Bell & Howell degreases 390,000 lbs. of metal parts between bath clean-outs

When Bell & Howell switched to a Nialk® Trichlorethylene bath recently, it was found that bath clean-outs could be extended to a full three months.

Previously the bath had to be cleaned *every ten days.*

With the new Nialk bath, Bell & Howell is degreasing 195 tons of small camera and projector parts between clean-outs. The parts are aluminum, brass, steel and zinc and can all be cleaned in the same bath.

The secret is in the stabilizer
The only thing different about the Bell & Howell bath is the Nialk stabilizer. Light, heat, air and acids have no effect on the bath. Even aluminum fines, which can sour trichlor fast, have no effect in the presence of the Nialk stabilizer.

This stabilizer is not extracted by water either; hence all of it is reclaimed during distillation and steam injection. So permanent is the stabilizer that the bath stays fresh and fully protected at all times.

Bell & Howell simply adds more trichlor as drag-out losses lower the bath level; they never have to replenish the stabilizer itself.

FREE BULLETIN • The whole question of stabilizers is so important to anyone concerned with vapor degreasing, we've written a bulletin specifically on the Nialk stabilizer and its advantages. Write for Bulletin 70 if you'd like a copy.

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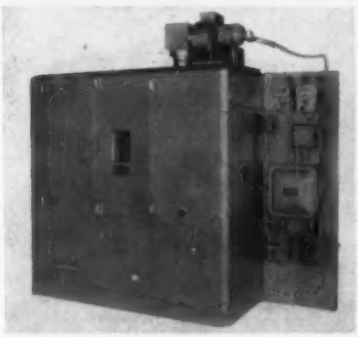
of the test cell to a control panel, permitting remote operation. Controls are connected to the tester by mechanical linkage. The tester uses both the Knoop and 136° diamond pyramid indenter. It employs a dual system of weights to enable the operator to select indenting loads in the range of 1 to 3000 g. or 1 to 10,000 g. The tester uses a microscope equipped with three dry objectives of 10, 20, and 50 magnification.

For further information circle No. 760 on literature request card, page 48-D.

Laboratory Oven

Despatch Oven Co. has announced a new design for their laboratory oven. The oven is electric heated and can be adapted to use steam or hot water at available pressures. Two swinging doors provide an oven opening 37 by 37 in. An observation window is inserted in one door. Safety features in-



clude: a special explosion relief panel in back, safety latches and safety chain on swinging doors; enclosure of motors and controls in explosion-proof housings, explosion-proof motors and strip heaters with welded connections to reduce spark hazards.

For further information circle No. 761 on literature request card, page 48-D.

Finishing

Hanson-Van Winkle-Munning Co. has announced three new chemical processes for cleaning and finishing. Alcond DX-100 is recommended for desmutting aluminum that has been etched in a caustic etchant and deoxidizing to remove surface oxides. Operations employing this product should be performed in tanks lined with polyvinyl coatings or made of stainless steel. Chem-Rite A-22 is an aluminum conversion coating process. It is supplied as a liquid concentrate. Solution is made by adding 5 gal. of Chem-Rite A-22 to 95 gal. of water. A brush coating is used for parts too large for dipping or too small to justify installation of tanks. The Zincalume process produces bright deposits in both still and barrel equipment. These bright deposits are produced at either high or low current densities with slight changes in composition or operating conditions.

For further information circle No. 762 on literature request card, page 48-D.

Combustion Control

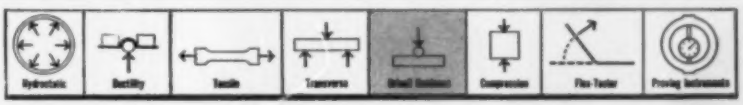
A new combustion control for continuous supervision of gas-operated burners in ovens, furnaces, boilers and other heating equipment has been announced by Protection Controls, Inc. The control prevents fires or explosions from build-up of combustible fuel mixtures in either single or multiburner installations. One plug-in subassembly (Flame-Pak) for each burner contains the electronic circuit. If a flame failure or fault occurs at any burner, the signal from the flame

electrode to its corresponding Flame-Pak unit is interrupted. This immediately breaks the circuit to the safety shut-off valve, and stops fuel flow to all burners in the system.

For further information circle No. 763 on literature request card, page 48-D.

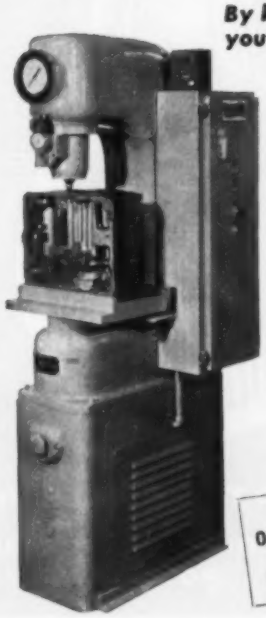
Ultrasonic Cleaner

A cleaner that has several simultaneous ultrasonic frequencies has been announced by McKenna Laboratories. The VT-700 operates at 400 kc., with frequencies ranging down to 20 kc. The higher frequencies remove dirt particles around 1 micron in size and penetrate into small crevices and recesses. The lower frequencies provide cleaning action required for larger dirt particles and provide cleaning on areas that are not accessible to high frequency because of shadowing. High-frequency cleaning is done



hardness tests increase plant capacity

By knowing the hardness of incoming parts you can reduce number of processing steps



Every production program has a bottleneck. Steel City Brinell testers can stop the broken-tool bottlenecks caused by too-hard parts.

For example, a maker of transmission cases has solved two problems with one "Color-Glance" tester. All incoming cases are tested; only hard ones need be annealed. Tool breakage is minimized, and limited annealing capacity is not overloaded.

Steel City "Color-Glance" Brinell hardness testers are high-production units. Relative hardness is shown by colored lights to reduce errors and fatigue. Optional equipment: workpiece locators, conveyor sections, counters, etc.

Steel City has solved many hardness-testing problems—laboratory, low-volume, portable. A standard machine may meet your needs.

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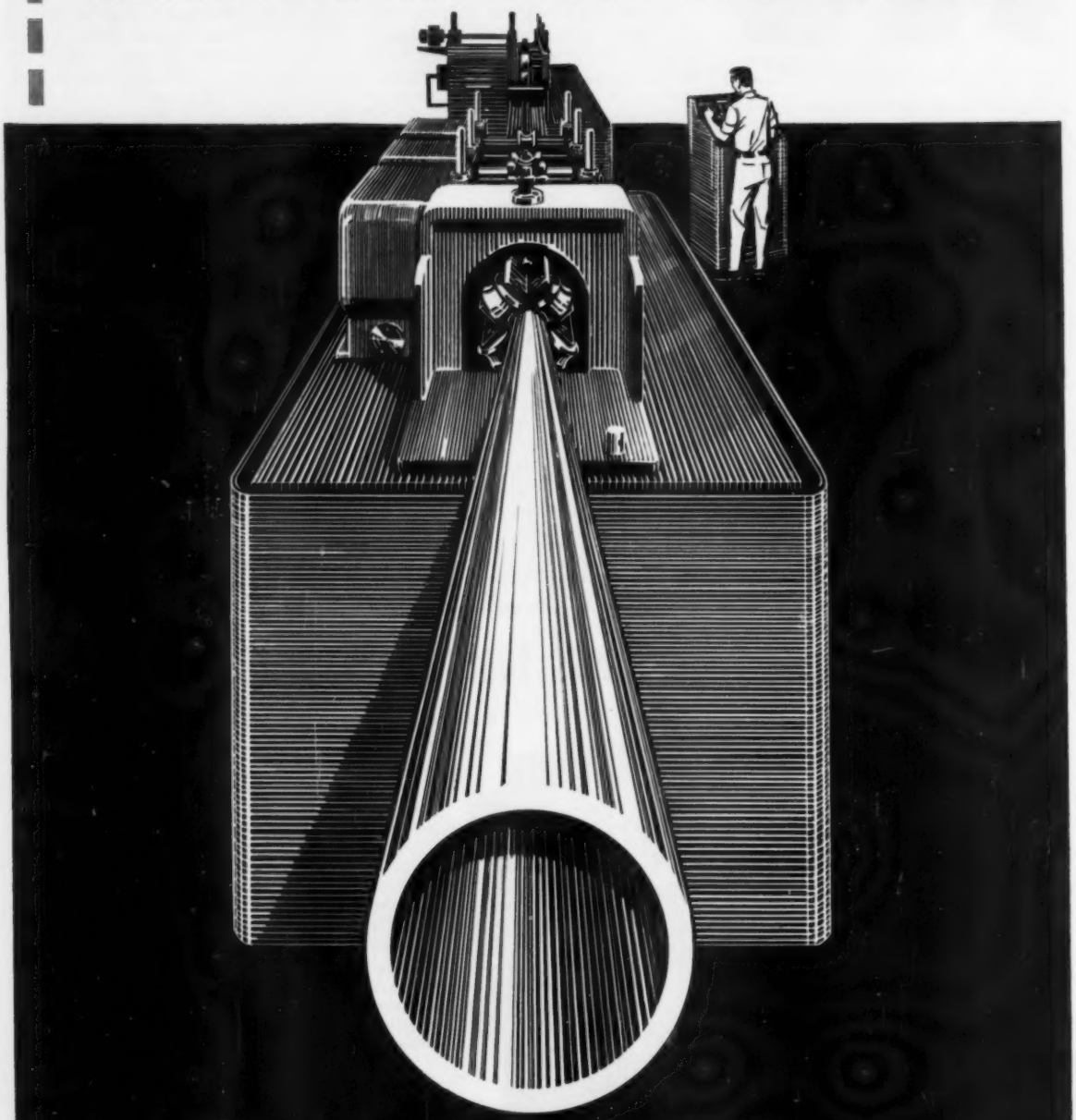

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COLD ROLL FORMING MACHINES
ROTARY SLITTING LINES

throughout the entire container, not in center area alone, allowing parts to be loosely stacked instead of being in

a single layer. Ultrasonic wash, ultrasonic rinse and drip dry complete the cleaning cycle. Cleaning containers, 12 in. in diameter by 12 in. deep, have a 24-qt. capacity.

For further information circle No. 764 on literature request card, page 48-D.

Metallizing Gun

An automatic metallizing gun for production, maintenance and research has been announced by the SpraRod Corp. The principal feature is the new two-position air cap that adjusts itself automatically for lighting and spraying. The gun is designed to handle all wire sizes from 15 gage to 3/16 in. and will handle all metals from molybdenum to lead. The wire feed range of 1.32 to 23.1 ft. per min. is accomplished by the dual-range air motor system.

For further information circle No. 765 on literature request card, page 48-D.

Tensile Testers

Portable tensile testers for bench or wall mounting have been announced by Steel City Testing Machines, Inc. These testers can perform standard tensile tests when mounted horizontally and tensile or compression tests when mounted vertically. A lower compression plate is available as an accessory when compression tests are anticipated. Tensile load is applied to

the test specimen by manually operating the hydraulic pump. The applied load is shown directly on the gage,

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IT'S NOT
"HOW THIN"

→ 0/8

BUT
HOW EXACT!

With the recent trend in strip metal towards thinner and thinner gauges, Somers, a pioneer in thin strip for nearly 50 years, is naturally among the leaders in rolling *ultra-thin* strip. But in addition to rolling production quantities of strip as thin as can be obtained anywhere in the world, Somers utilizes exclusive techniques and equipment to make sure that every foot of metal is up to the most exacting standards.

1. Accu-Ray nuclear gauging to assure absolute uniformity of thickness throughout.

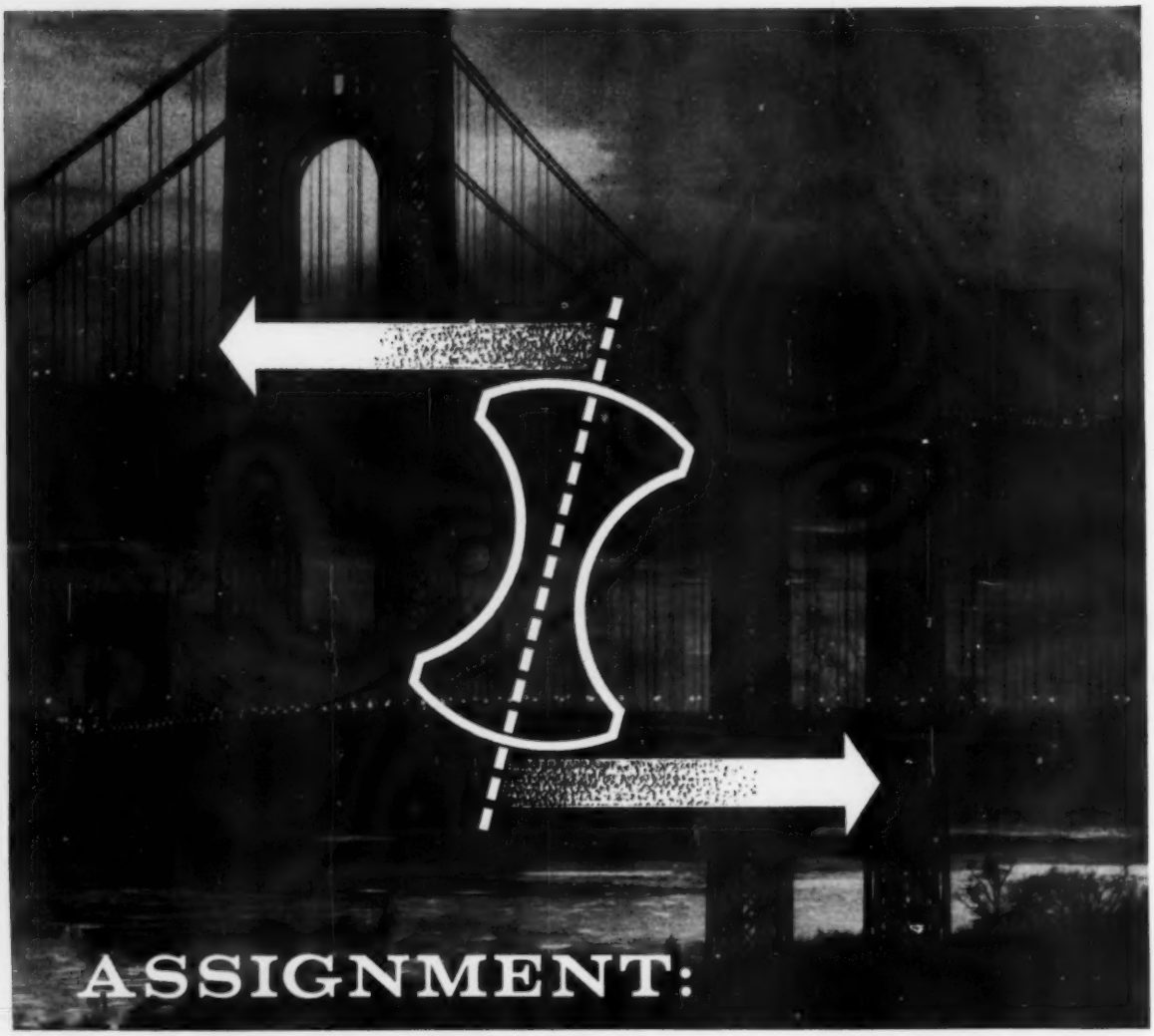
2. Unique rolling mill for strip from .001" down, makes possible extremely close control of the final pre-anneal temper, and uniform accuracy of the final temper.

3. Experience exclusively with thin strip metals gives Somers an unmatched background in engineering *ultra-thin* strip to meet all special requirements.

NEARLY
FIFTY
YEARS

FOR EXACTING STANDARDS ONLY
Somers

Somers Brass Company, Inc.
106 BALDWIN AVE., WATERBURY, CONN.



EXPANSIVITY

How Lukens *Application Research* can help you find the right steel plate for the job

In solving problems of expansivity, the experience of our Application Engineering staff is long and varied. And it's yours for the asking.

For example, a growing number of bridges expand and contract on *bearing plates* of Lukens stainless-clad steel. Extensive research led to the first such application. Tests run jointly with a consulting firm and a large university put Lukens clad steel plate through 2 million passes under a 100,000 pound loading—without harm. There was actually evidence that the bond between the backing steel and its stainless cladding grows stronger.

All the safety factors of corrosion-resistant stainless are present in stainless-clad—at significantly lower cost than 100% high alloy.

Since this initial research, many such bearing plate applications have been made—and their performance compared with that of other materials. Today, The Walt Whitman, Greater New Orleans, Rappahannock River, Throggs Neck, and a number of smaller highway bridges, are cradled on these safe, money-saving plates. The knowledge accumulated by Lukens' Application Engineers in this area and others is available to help guide you in your design problems.

That's why we say, *if your assignment is expansivity, let it be our assignment too.* Contact Manager, Application Engineering, **F109 Services Building, Lukens Steel Company, Coatesville, Pa.**

ASK FOR THE BULLETIN ON BRIDGE BEARING PLATES

Helping Industry Choose Steels That Fit The Job

LUKENS

FURNACES
TO HEAT TREAT OR SHAPE METALS MORE EFFICIENTLY

CAR HEARTH FURNACES

ROTARY HEARTH FURNACES

PIT-TYPE FURNACES

HI-HEAD FURNACES

BELT TYPE FURNACES

CHAIN CONVEYOR FURNACES

Write for technical data and catalogs, on the above and many other R-S Furnaces to...

R-S FURNACE COMPANY, INC.
North Wales, Pa.

R-S FURNACES

which includes a maximum-indicating hand. Connection between the pump and the tester is through a flexible rubber hose so the maximum reading will not be affected by fracture reaction. Since the pump and gage unit must be bench mounted, the length of the hose can be specified longer than the standard 18 in. when the tester is to be mounted on the wall. Testers are available in two general sizes with capacities from 5000 to 20,000 lb. or 20,000 to 40,000 lb.

For further information circle No. 766 on literature request card, page 48-D.

Testing Furnace

Marshall Products Co. has announced a high-vacuum furnace designed for tensile and creep testing of metals and alloys at temperatures up to 4000° F. The unit measures about 44 in. in over-all height, 11 in. in O.D. and consists of a tantalum heating element surrounded by tantalum and molybdenum radiation shields, water-cooled tank and bellows assemblies, tantalum plate and rod electrode assembly, vacuum pumping and

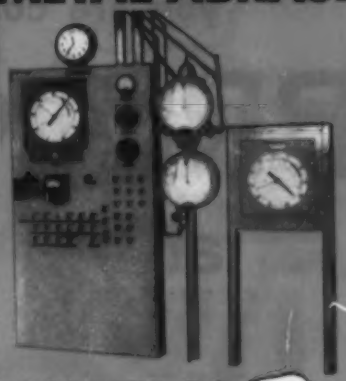
gaging ports. The furnace operates on approximately 14 v., 1600 amp. in conjunction with special transforming equipment, and maximum input to the heating element is 25 kw. Specimen is assembled with tension rods, then lowered into the vacuum chamber from the top. The furnace can be evacuated at room temperature to a pressure of 1×10^{-5} mm. Hg with standard pumping equipment; normal pressure at 4000° F. is in the range of 2×10^{-4} mm. Hg.

For further information circle No. 767 on literature request card, page 48-D.

Plating Anodes

Allied Research Products, Inc., has announced a new anode for zinc plating. Called the "roll-top" anode, it is

Now!
METAL ABRASIVE



CUSTOM MADE for YOU

The newest development in manufacture of metal abrasive is custom-made "Malleabrasive"—job-lot-made to meet individual cleaning conditions.

By means of new, highly specialized processing techniques and equipment used only by us, we can make the type of "Malleabrasive" shot or grit that will do your particular job best, at lowest cost to you.

Why put up with general purpose abrasives when you can have "Malleabrasive" tailor-made for you? We'll welcome the chance to tell you how you can benefit. Write us.

THE GLOBE STEEL ABRASIVE CO.
Mansfield, Ohio

Sold by many leading distributors of foundry supplies from coast to coast.

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BRINKMANN RESEARCH EQUIPMENT EXHIBIT

at the 1959 METAL SHOW

in CHICAGO

If you can't make the trip and wish to be informed about latest developments send in the coupon at the bottom of this ad to receive descriptive literature on any of the items which may be of interest to you.

BRINKMANN Sales Offices are now located in Houston, Cleveland, Philadelphia, Miami, San Francisco

1 Dilatometers
a) Automatic b) Manual

2 Differential Thermo Analyzers

3 ZEISS-SIEMENS Television Microscope

4 1500°C Molybdenum Furnaces

5 1800°C Rhodium Furnaces

6 Large Vacuum Drying Ovens

7 Polarecord, Automatic recording polarographic Analyzer

8 SEDIBAL, Automatic particle size Analyzer

9 ZEISS Automatic Photo Microscopes
a) 35mm Film b) 4x5 Film or plates

10 Ultrasonic Micro Jackhammer

11 Micro Manipulators

12 Vickers Metallograph

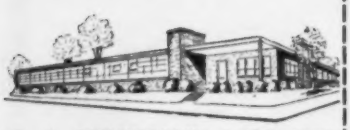
13 Vacuum Micro Balance, recording

14 Thermo Balance, recording

15 Potentiograph, Automatic recording universal titrator

16 Hi-temperature thermometers

BRINKMANN



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115 CUTTER MILL ROAD
GREAT NECK, L. I., N. Y.

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MP-59

cast in a modified oval form. This shape provides approximately 20% more surface area than ball anodes, yet allows the anode to roll easily into a curved hanger basket or back-feed chute.

For further information circle No. 768 on literature request card, page 48-D.

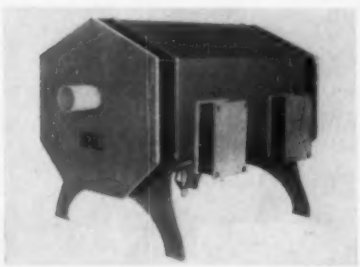
Time-Cycle Controller

The Bristol Co. has announced a new time-cycle controller that can time control ten different variables. Ten pneumatic or electric pilots operate simultaneously or in any sequence, each pilot performing up to 24 operations. Pilots can be changed or added. Dogs set on the periphery of the timing disk determine the timing of pilot operations. Intervals between operations can be as brief as 4 sec., and timing disks range from 0 to 15 min. to 0 to 360 min.

For further information circle No. 769 on literature request card, page 48-D.

Tube Furnaces

High-temperature tube furnaces have been announced by the Sentry Co. They come in three sizes with standard tube bores up to 3½ in. and 18-in. long heating chambers. Maximum temperature is 2750° F. Furnace



heating time from cold to 1825° F. is about 25 min.; 2375° F. is normally reached in 45 min. and maximum operating temperature in about 90 min. Automatic temperature and current regulating controls are available.

For further information circle No. 770 on literature request card, page 48-D.

Indicator

A new instrument for use in measuring and control systems which employ resistance strain gage transducers has been announced by the Electronics & Instrumentation Div., Baldwin-Lima-Hamilton Corp. The disk indicator may be used for weight and load measuring systems, pressure systems, torque and horsepower measuring systems. It requires less than 1 sq. ft. of panel area for mounting and features a horizontal read-out window, and up to 500 dial graduations for fast, accurate reading.

For further information circle No. 771 on literature request card, page 48-D.

Ultrasonic Cleaner

An ultrasonic cleaner for applications in which high energy density is required has been announced by National Ultrasonic Corp. The unit has a 2-gal. tank of stainless steel; the tank is 9 by 6 by 10 in. The gener-

ator, 115 v., single-phase, 60-cycle, is designed for continuous operation. It delivers an average power output of 125 w. and produces peaks of 500 w. Features include a 0 to 60-min. timer, one-tube oscillator, provision for remote control of equipment, front panel switching which permits a choice of either of two transducers, and circuit-breaker and three-wire ground protection.

For further information circle No. 772 on literature request card, page 48-D.

Refractory

A new magnesium oxide ceramic has been announced by the Refractories Div., Carborundum Co. When used for crucibles, this new product combines high purity with strength and resistance to molten-metal attack. The composition is formed into such shapes as tubes, crucibles, plates, disks, bars and rods. Density of the refractory is 3.3 to 3.4 g. per cu.cm.,

modulus of rupture, 20,000 psi. and compressive strength, 90,000 psi.

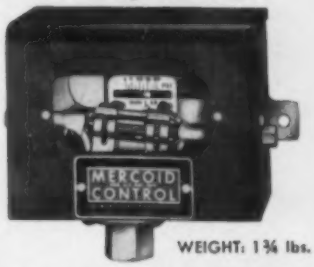
For further information circle No. 773 on literature request card, page 48-D.

NEW

Small, Lightweight

MERCOID PRESSURE CONTROL

AP-153



WEIGHT: 1¾ lbs.

FOR MEDIUMS NOT INJURIOUS TO STEEL OR SILVER SOLDER

CIRCUIT

SP-DT HERMETICALLY SEALED MERCURY SWITCH (4A. 115V., 2A. 230V.)

Provides any of following operations:

1. *Single Pole—Cut-in high (close on rise)*
2. *Single Pole—Cut-in low (open on rise)*
3. *Single Pole—Double Throw*

OPERATING RANGE

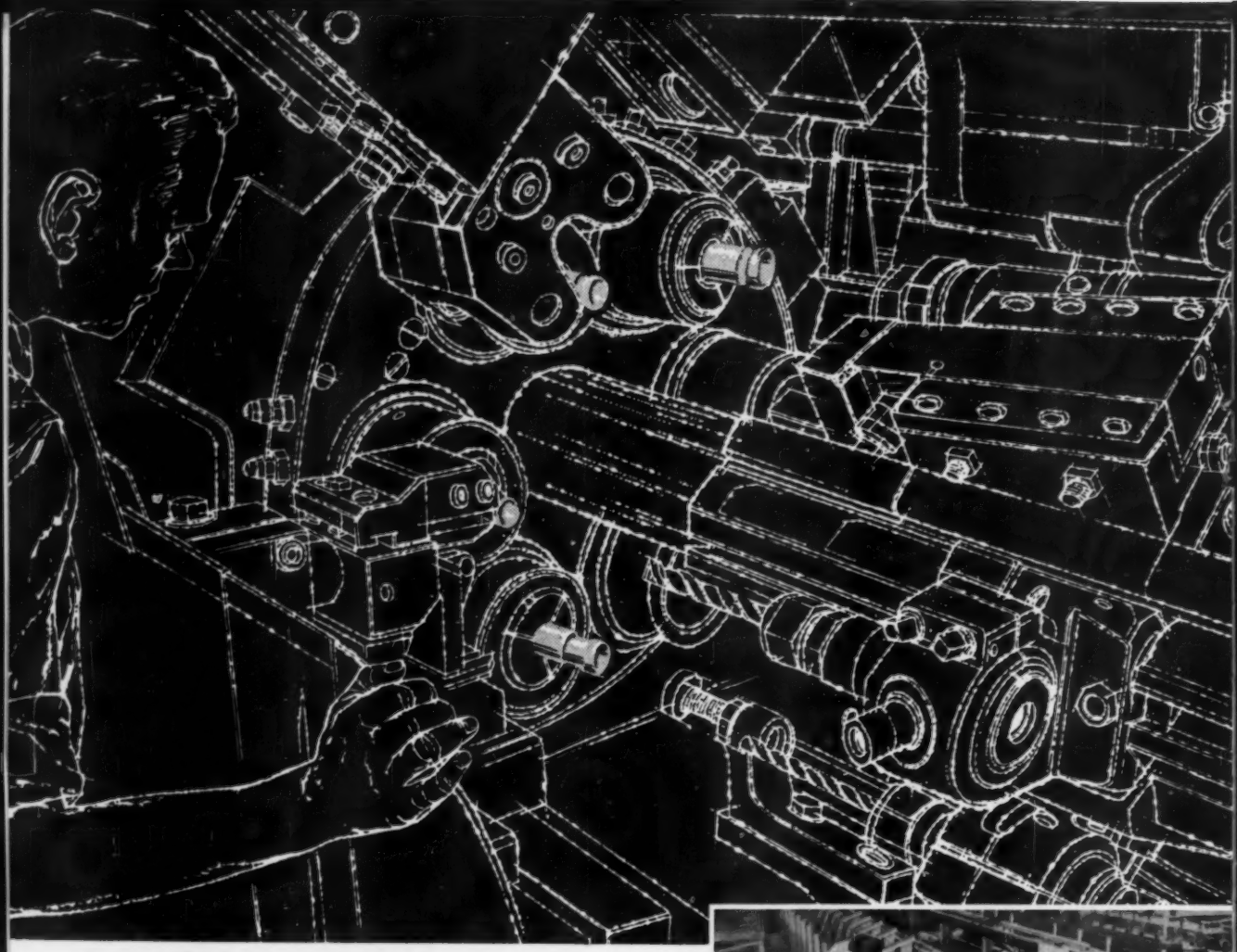
Adjustable Operating Range	Differential Fixed (Factory Set)	Maximum Surge Limits
1 to 20 psig	0.5 psig.	30 psig.

CONSTRUCTION

ADJUSTMENT: External
PRESSURE ELEMENT: Fairprene diaphragm
PRESSURE CONNECTION: ¼" I.P.S.
MOUNTING: Has two mounting ears (one on each side of control) or control may be pipe mounted by means of the ¼" I.P.S. bottom connection.
INTERNAL WIRING CONNECTIONS: 3 post terminal block.
CASE: NEMA 1—Heavy gauge steel, cadmium plated. Steel cover (with glass front) finished in charcoal-gray.

WRITE FOR BULLETIN 02

THE MERCOID CORPORATION
4201 Belmont Ave., Chicago 41, Ill



The Ultimate Test

The ultimate test of quality in stainless steel bars takes place in screw machine production, where every bar is literally cut to pieces.

The Perry-Fay Company, Elyria, Ohio, a leader in screw machine production, has been subjecting J&L bars to this demanding production-line test for more than a year, **without a single failure, without a single reject.** Perry-Fay reports: "We consistently get superior surface finish, closer tolerances, fully formed rolled threads with J&L stainless bars."

Whether you need stainless steel bar stock for high-speed, high-production operations, or a single bar for extraordinary requirements, turn to J&L. J&L leads the industry in melt shop standards for stainless steel, the point where quality starts—and new production profits begin.

Careful attention to every production detail is the key to J&L quality.

Plants and Service Centers:
Los Angeles • Kenilworth (N. J.) • Youngstown • Louisville (Ohio) • Indianapolis • Detroit

J&L
STAINLESS
SHEET • STRIP • BAR • WIRE

Jones & Laughlin Steel Corporation • STAINLESS and STRIP DIVISION • Box 4606, Detroit 34

Engineered by the most outstanding

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INSTRUMENTS

At the metal show.

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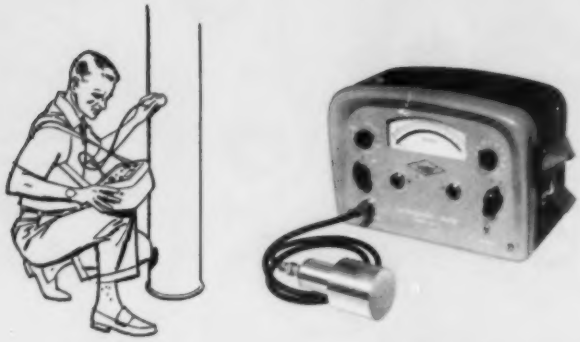

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g instrument designers in the Ultrasonic Industry

ASONIC THICKNESS GAGE

New, battery operated, completely transistorized, thickness gage.
Using pulse echo method, detects changes in metal thickness even in corroded or rough surfaces.
Small (7″ x 7″ x 10″), lightweight (10 lbs.).
Easy to read meter, directly calibrated in inches.
Particularly useful in inspection of high pressure pipe, storage vessels and ship hulls for thinning and corrosion.

LTRASONIC REFLECTOSCOPE

New Unitized Ultrasonic Reflectoscope provides maximum flexibility through low cost interchangeable plug-in units.
Designed to accommodate various components, choice of frequency ranges, alarm and recording channels, attenuation correction, counting and totalizing channels, etc.
Economical building block method permits adding to instrumentation to meet increasing or changing testing requirements.

LTRASONIC REFLECTOSCOPE

Latest concept in ultrasonic testing equipment.
The most advanced instrument for lab and production line testing, compact for use on bridge or bench.
Exclusive features: Four instantaneous or continuous alarm channels with separate channel indication.
Plug-in receivers with frequency ranges from 1 to 25 mcs.
Large 12″ CRT with dual trace 2-color display.
Double slope curves for distance amplitude correction—both near-zone and attenuation.

Sperry Products, Inc.

Danbury, Connecticut

PLEASE SEND THE FOLLOWING:

RUSH METAL SHOW TICKET (save $1)

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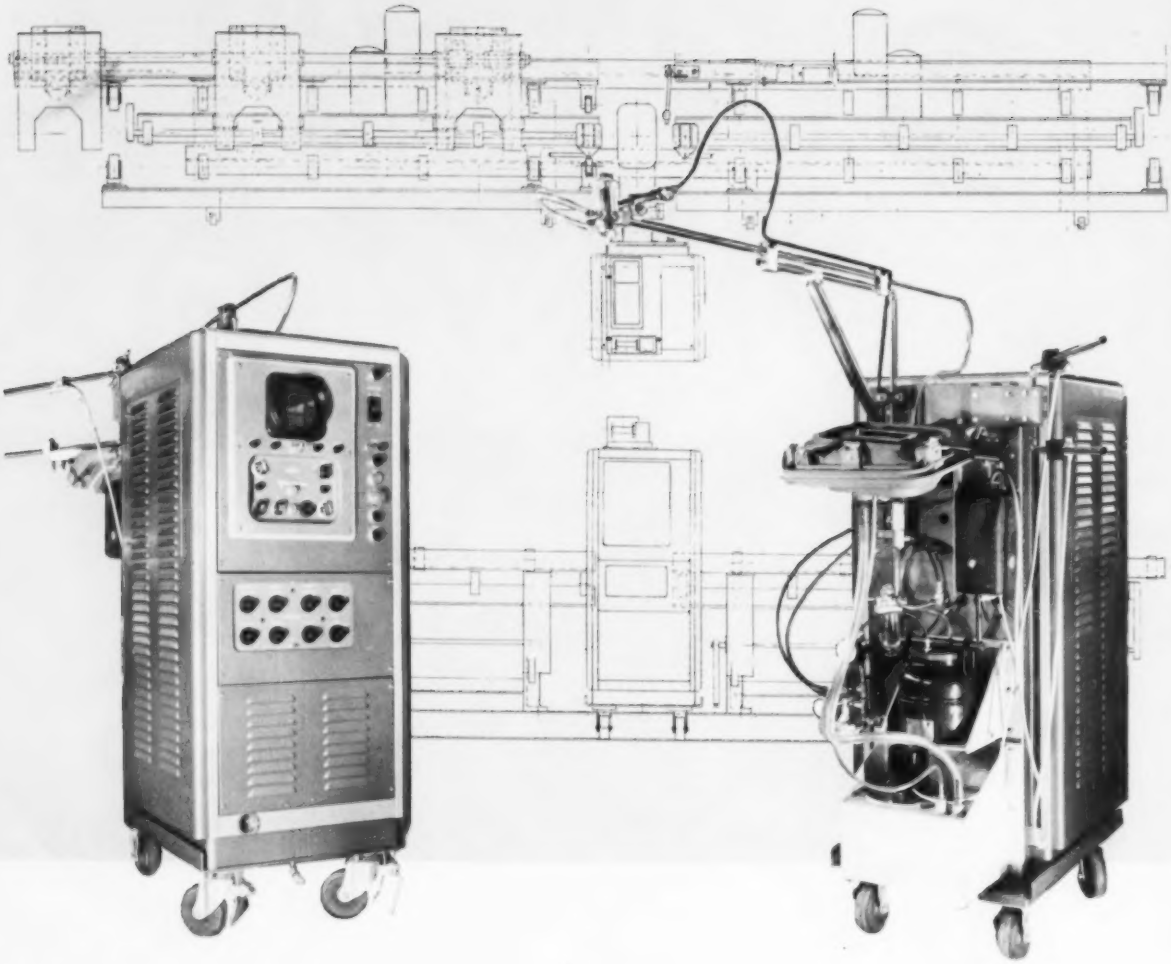


AUTOMATIC ULTRASONIC TESTING SYSTEMS

FOR PRODUCTION QUALITY CONTROL

Sperry now makes available automatic production testing on an economical packaged basis.

These systems are designed to test billets, bar stock, sheet, plate, tubing, etc. at production speeds.

Consisting of the necessary instrumentation, scanning equipment, recorder, alarms, and defect markers, as well as material handling equipment, the packages are truly complete testing systems.

For the complete story, check off and mail attached reply card to arrange a visit by a Sperry sales engineer.

Sperry Products, Inc.

Danbury, Connecticut

This nut saved money because we made the hole

You're looking at one of the nuts that fits a casing bolt on a General Electric steam turbine. These nuts have to be of a special alloy steel because they are highly stressed at operating temperatures. The steel must have very high "creep strength"—keep its strength and dimensions at high temperature.

The General Electric Company was making these nuts from alloy steel bars. That was expensive because it meant drilling a large hole as the first operation.

Timken Company metallurgists said they could make seamless steel tubing of the same analysis and properties. And with the hole already there, this would eliminate the rough drilling operation—save a major machining cost.

We furnished Timken seamless steel tubing of the proper size so that after threads were cut, and the castellated heads machined, the nuts were finished up to the specified dimensions. And because Timken steel tubing is rotary pierced, it has the forged quality to give these nuts the strength they need.

This is another of the hundreds of tough steel problems that Timken Company metallurgists solve in every corner of industry. Many of these problems are apt to be much like yours. Why not let our 40 years of steelmaking experience work for you? Have your next steel problem stamped "Solved" in jig time. Call in Timken Company metallurgists. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". *Makers of Tapered Roller Bearings, Fine Alloy Steels and Removable Rock Bits.*

WHEN YOU BUY TIMKEN STEEL YOU GET:

1. Quality that's uniform from heat to heat, bar to bar, order to order
2. Service from the experts in specialty steels
3. Over 40 years experience in solving tough steel problems

TIMKEN ALLOY STEEL AND SEAMLESS STEEL TUBING ARE AVAILABLE FROM WAREHOUSE STOCKS IN 44 CITIES IN THE UNITED STATES

COMBINES SUPERB WELDABILITY WITH EXTRA STRENGTH

N-A-XTRA

BEST LOW-ALLOY EXTRA-STRENGTH STEEL YOU CAN BUY

When only the strongest steels will do, specify N-A-XTRA HIGH-STRENGTH. This low-alloy heat-treated steel is now available in minimum yield strengths ranging from 80,000-110,000 psi.

Along with this great strength, N-A-XTRA is readily formed and fabricated. It can be welded by any process. The most drastic welding tests on N-A-XTRA have shown no underbead cracking, even when plate temperatures are as low as —60°F.

Because N-A-XTRA is nearly three times stronger than mild carbon steels, it gives designers an opportunity to eliminate useless dead weight from finished products and realize substantial savings. Let us show you how N-A-XTRA HIGH-STRENGTH steel can do a job for you. Write Great Lakes Steel Corporation, Detroit 29, Michigan, Dept. E-7

GREAT LAKES STEEL

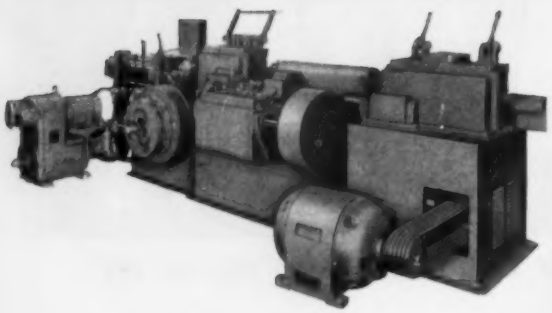
A DIVISION OF NATIONAL STEEL CORPORATION

Meet your Profit Challenge with LEWIS Wire Straightening and Cutting Machines

There is a Lewis machine for every possible purpose in the wire straightening and cutting field. And Lewis engineers are constantly working on new designs and developments to further improve performance. There are 46 models in the Lewis line.

Lewis machines are designed to do the highest quality job of wire straightening and cutting in rounds as well as shapes.
For speed, accuracy and clean cutting, they have no equal anywhere.

In every possible way, Lewis Machines meet the challenge of today's production requirements.



Lewis No. 11-FA Travel-Cut with Flying-Shear Cut-Off. Capacity ½" to ¾" diameter, 75-175 FPM. Rear view with guards removed showing Air Clutch and drive.

The combination of Air Brake, Air Clutch and Variable Speed Drive permits higher cut-off speeds... and allows infinite adjustment of the flywheel for perfect synchronization of cut-off and wire feed speeds... rod can be cut WITHOUT SPOT SWELL.

Lewis No. 20-F Travel-Cut SHAPE Straightening and Cutting machine. Capacity 5/16" to 5/8" square, hex or equivalent area in flat stock.

The Travel-Cut Flying-Shear Cut-Off is particularly advantageous on shape machines to better synchronize the cut-off with the through speed of the wire. This is necessary to eliminate roll rub marks and reduce roll wear to a minimum.

N.B.

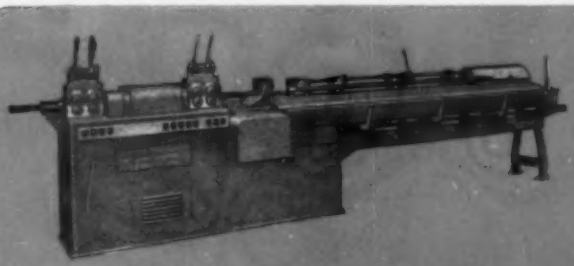
A New 1" Machine.

The new Lewis No. 12-FA High-Speed, Flying-Shear type Wire Straightening and Cutting Machine is now being developed to handle rod up to 1" in diameter from coils at output speeds much greater than on any existing equipment.

TIMKEN BEARING EQUIPPED

Lewis No. 2CV4 Automatic Wire Straightening and Cutting Machine with variable speed drive and Dual-Center Straightening Arbor. Capacity 1/16" to 1/4" diameter. No. 2CV5 Capacity 1/16" to 5/16" diameter. Feed speeds up to 200 FPM.

The Lewis 2CV Series can be quickly converted to handle shapes by installing our interchangeable Roll Straightener in place of the Dual-Center Rotary Straightener Arbor.

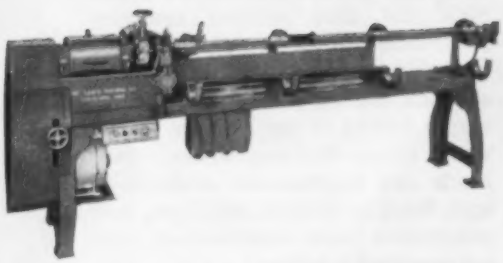


Lewis No. 4-FHA Travel-Cut Automatic High-Speed Flying-Shear Wire Straightening and Cutting Machine with Wichita Air Clutch and Air Brake. Capacity Mild Steel, 3/32" to 1/4" diameter. High Carbon, Alloy and Stainless, 5/16" diameter, Speeds up to 500 FPM.

The Dual-Center Straightener Arbor (Pat. Pend.) permits use of close centers for small diameters and long centers for the larger diameters for precision straightening over entire range of machine.

Lewis No. "O" Electric-Air. Especially designed for straightening and cutting fine wire sizes. Capacity .012" minimum to .0625" music wire, .072" spring wire, .080" basic wire.

Extremely fast air-operated cut-off eliminates Flywheel and Clutch...Variable Speed Drive provides wire feed range of 15-90 FPM... precision length gauging, plus or minus .0025 in 6" length ... highest quality finish.



Lewis No. 1-C Automatic Wire Straightening and Cutting Machine. 1/16" to 1/8" capacity.

Greater flexibility with Multiple Speed Drive in a low cost machine. High-speed Five-Die Rotary Straightener Arbor, mounted on ball bearings. Available with super-sensitive electric trip mechanism.

LEWIS

MACHINE COMPANY
3441 EAST 76TH STREET
CLEVELAND 27, OHIO

ROTATING BURNER

Flame Heating Machines!

- **flame head spins within the area of the part to be heated**
- **simplifies spin hardening of parts difficult to rotate—eliminates expensive fixtures**
- **cuts hardening costs all around**

This newest development of the Meta-Dynamics Division Heat Treating Laboratories brings lower costs to precision selective flame heating of a wide range of parts, because the flame head rotates—*not* the work. The gas-tight rotating joint of the burner has undergone more than 1000 hours of test, with no sign of leakage.

The rotating burner and workholding fixture mount on the flat bed of the basic machine, which contains a quench tank and part removal conveyor. Automatic timing, temperature and quenching control are provided. A separate control cabinet provides accurate control of gas, oxygen, air and water. Other "building blocks" (flame heads and fixtures) are available for such work as brazing and spot, spin, progressive and combination spin-progressive hardening.

For your heat processing work, look to the Cincinnati Flamatic for lowest cost flame heating . . . and the Cincinnati Inductron (built in 15, 30, 50 KW capacities) for lowest cost induction heating. Call in a Meta-Dynamics Division field engineer for full details.

TYPICAL PARTS SUCCESSFULLY HARDENED BY THE FLAMATIC ROTATING BURNER

INTERNAL THREAD of steering knuckle control arm, a pearlitic malleable casting, hardened to Rc 58-60. I.D. is 1¹³⁄₁₆"; thread length, 1⅛"; overall part length, 22½".

INTERNAL TEETH of SAE 1052 Ring Gear, hardened to Rc 58-60. Gear I.D. is 5¼"; tooth face, ⅝".

inductron
flamatic
hardening machines

META-DYNAMICS DIVISION
Machines for Metal Forming and Heat Treating

THE CINCINNATI MILLING MACHINE CO.
Cincinnati 9, Ohio, U.S.A.

CINCINNATI

APPLICATION and EQUIPMENT new literature

775. Abrasive Cleaning
Catalog 57-WX on brush types, sizes, speeds, filaments. Aids to power brush selection. *Pittsburgh Plate Glass*

776. Alloy Steel
12-page data sheet on Hy-Tuf alloy steel. Composition, properties, annealing. Hardenability band, TTT curves, bend tests. *Crucible Steel Co.*

777. Alloy Steel
14-page bulletin on two chromium-nickel alloy steels. Properties, working instructions, heat treatment, recommended uses. *Carpenter Steel*

778. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

779. Alloy Steels
46-page Booklet 415-C on alloy steels. 9 pages of tables giving chemical composition ranges, limits. Grain size, heat treatment, quenching mediums. *Bethlehem Steel Co.*

780. Alloys
Pamphlet on iron foundry alloys details composition, uses and advantages of 31 ferroalloys for both cupola and electric furnace irons. *Vanadium Corp.*

781. Aluminum
8-page bulletin on aluminum casting alloys. Properties; selection of casting method; pig, ingot and billet compositions. *Metals Div., Olin Mathieson Chemical*

782. Aluminum Bronze
8-page booklet on aluminum bronze bearing material which is forgeable, corrosion resistant. *Mueller Brass*

783. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

784. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

785. Aluminum Strip
20-page booklet on how it is made, sizes and weights of coils. Technical data on aluminum alloys used. *Scovill*

786. Arc Welders
Folder on Idealarc machine for all manual arc welding applications, for a.c. and a.c.-d.c. use shows basic and optional equipment. *Lincoln Electric Co.*

787. Atmosphere Equipment
4-page bulletin on new line of inert atmosphere generators showing new features, flow chart, utilities required. *Gas Atmospheres*

788. Atmosphere Furnace
Bulletins T-1090 and 1091 on atmosphere tube units give application, specifications, operation data. *Lindberg Engineering*

789. Atmosphere Furnace
Bulletin HD-1 on batch-type controlled atmosphere furnace. Specifications, atmosphere circulation. *Dow Furnace Co.*

790. Atmosphere Generators
22-page bulletin describes equipment that produces four basic types of atmospheres for heat-treating applications. *Sunbeam Equipment Corp.*

791. Atmospheres
8-page Bulletin SC-155 discusses following controlled atmospheres: RX, DX, NX, HNX, AX, HX. Compositions, applications, effects on steel, drawings of generators. *Surface Combustion*

792. Belt Surfacing
12-page discussion of procedure and equipment for rough grinding of metallurgical specimens. Metal Digest, V. 2, No. 5. *Buehler, Ltd.*

793. Beryllium Copper
4-page article on hot-hardness properties of four beryllium copper castings alloys. *Brush Beryllium Co.*

794. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal," contains uses, formulas, calculations. *W. M. Chace*

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Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

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16-page brochure on use and specifications of centrifugally cast cylinders, other products. *Sandusky Foundry & Machine*

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828. Creep Testing
Bulletin RR-13-56 on testing machines for creep and stress-rupture tests. Tables. *Riehle*

829. Creep Testing
Bulletin 4420 describes long-time creep test machines, creep-rupture machines and relaxation machines. *Baldwin-Lima-Hamilton*

830. Crucible Melting
Nontechnical bulletin on crucible melting gives standard nomenclature, chapters on furnace maintenance, burner design, charging and melting, and other factors. *Crucible Manufacturers' Assoc.*

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Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

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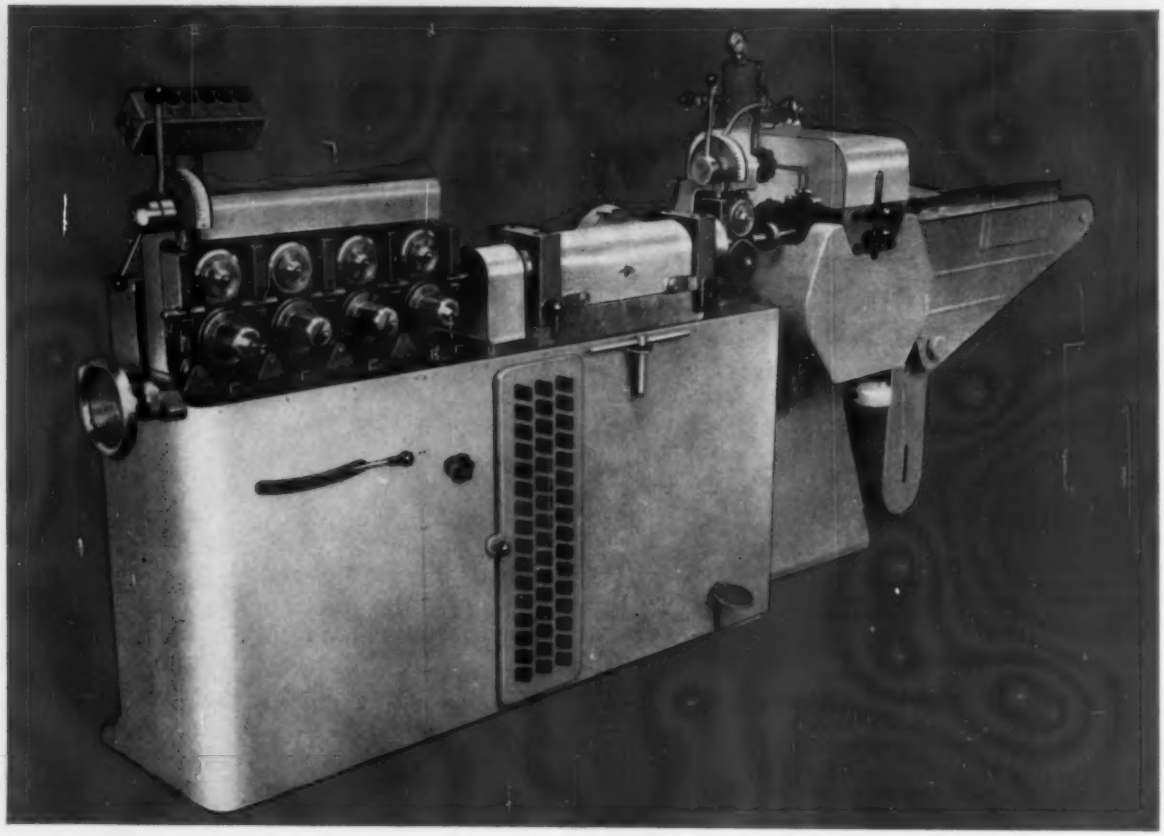

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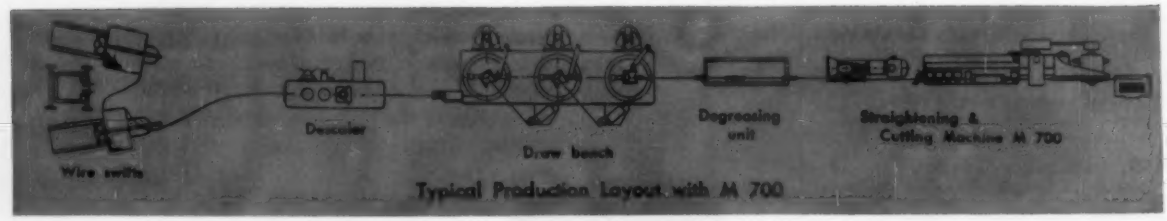

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4-page brochure describes process for plating selected areas without immersion tanks. *Sifco Metachemical*

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New 4-page catalog on flame hardening steels, cast iron, nodular iron. Parts flame hardened. Hardnesses produced. *Chicago Flame Hardening Co.*

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874. Hardness Tester
Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness tests. *Opto-Metric Tools, Inc.*

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4-page bulletin on portable metal hardness tester for any shape or metal. Ranges, features. *Newage Industries*

876. Hardness Testers
20-page Catalog No. DH-326 on models, applications and how to use superficial hardness testers. *Wilson Mechanical Instrument Div.*

877. Hardness Testing
Bulletin A-18 on Alpha Co. Brinell hardness testing machines. *Gries Industries*

878. Heat-Resistant Alloys
Data sheet on RA309 gives creep, stress-rupture and mechanical properties, composition. *Rolled Alloys, Inc.*

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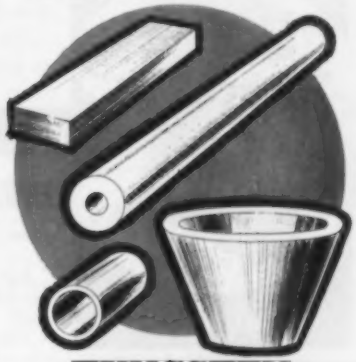

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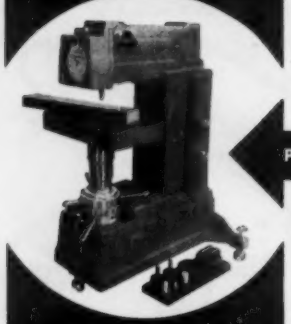

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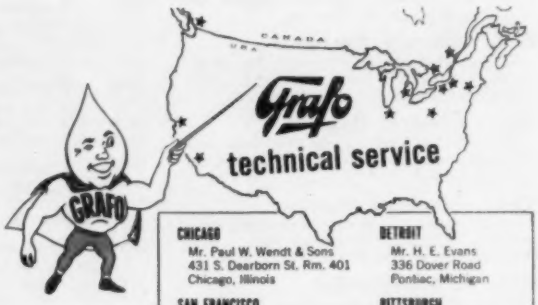

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887. Heat Treating Furnaces

32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones, Inc.*

888. Heat Treating Pots

Bulletin 110 gives data on sizes and shapes of cast nickel-chromium solution pots. *Fahralloy*

889. Heat Treatment

Bulletin 200 on car hearth, rotary hearth, pit, roller hearth, belt, chain, pusher, and "hi-head" furnaces. *R-S Furnace*

890. Heaters

Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

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Bulletin on cast heating element used in electric furnace. Various methods of mounting. *Electric Furnace*

892. High-Strength Steel

4-page bulletin on Yoloy "E" steel. Properties, corrosion resistance and strength. *Youngstown Sheet & Tube*

893. High-Temperature Bolts

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Bulletin 990 gives specifications and pumping speed curves of two models. *F. J. Stokes*

897. Inconel

24-page Bulletin T-7 on properties of Inconel. 22 property tables. Corrosion resistance and working characteristics. *International Nickel*

898. Induction Brazing

Folder tells how tips of carbide may be brazed on tool shanks. *Ohio Crankshaft*

899. Induction Hardening

Bulletin M-1938 on induction hardening machine gives advantages and application. *Cincinnati Milling Machine*

900. Induction Heating

Bulletin 20-30 on high-frequency power source and control unit. Diagrams of units. *Inductotherm Corp.*

901. Induction Heating

12-page booklet on the ABC's of induction heating for extrusion, forging, brazing, heat treating and metal joining. *Magnethermic*

902. Induction Heating

High Frequency Review contains article on high-temperature fatigue tests using induction heating. *Lepel High Frequency Laboratories*

903. Induction Heating

Induction Heating News No. IHN-7 describes applications of induction heat in heat treating of metals. *Induction Heating*

904. Industrial Fans

Bulletins IF-100, TB-109, HF-100 and BB-105 on industrial fans and blowers. *General Blower Co.*

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16-page booklet on magnetic particle inspection. Equipment, uses, kinds of defects that can be found. *Magnaflux*

906. Inspection

Bulletin on Spotcheck dye-penetrant inspection. Advantages, prices. *Magnaflux*

907. Investment Casting

"Pointing the Way" presents seven case histories on advantages of investment castings. *Engineered Precision Casting*

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Complete information on multi-motion laboratory test specimen dies. *Haller*

909. Laboratory Equipment

Bulletin on cutting test specimens describes methods for different types of metals. Price list. *Sieburg Industries*

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Data on cathodic vacuum etcher for metallographic samples, complex alloys and dispersions that are difficult to etch. *Nuclear Materials & Equipment Corp.*

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Information on 4600° F. laboratory furnace. Bottom-dropping hearth; for use with oxyacetylene or natural gas burners. *Zirconium Corp.*

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8-page booklet, "Biggest Ounce of Protection," tells of lubrication with colloidal graphite products. *Grafo Colloids*

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Bulletin 581 on colloidal graphite dispersions for industry. 17 uses listed. Tables on concentrated and ready-to-use solutions. *Graphite Products Corp.*

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40-page bulletin on designing with magnesium and titanium. Properties, formability and fabricating processes. *Brooks & Perkins*

915. Magnesium

53-page book on wrought forms of magnesium. Includes 44 tables. *White Metal Rolling & Stamping Corp.*

916. Magnesium-Zirconium

10-page reprint on an investigation of zirconium chloride, zirconium fluoride, 40% zirconium-magnesium material for making magnesium-zirconium alloys. *Titanium Alloy Mfg. Div.*

917. Magnetic Alloys

Bulletins 52-100 and 52-151 on applications, characteristics and annealing of Hipernik, Hipernom, Hiperco and Con-

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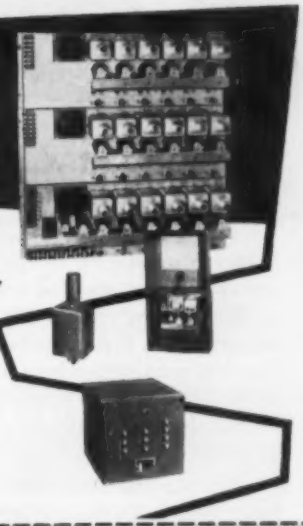

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(Continued on page 48-A)

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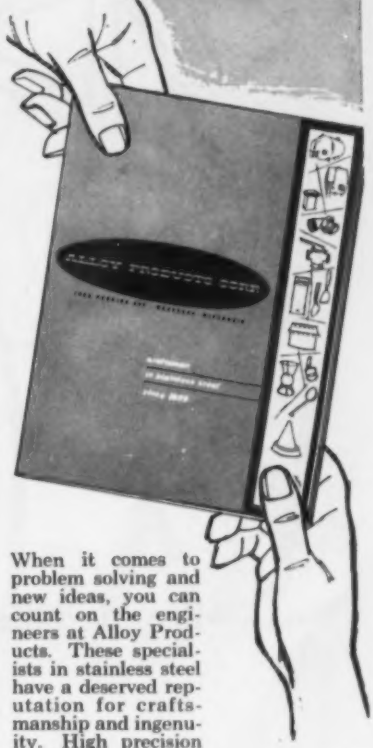

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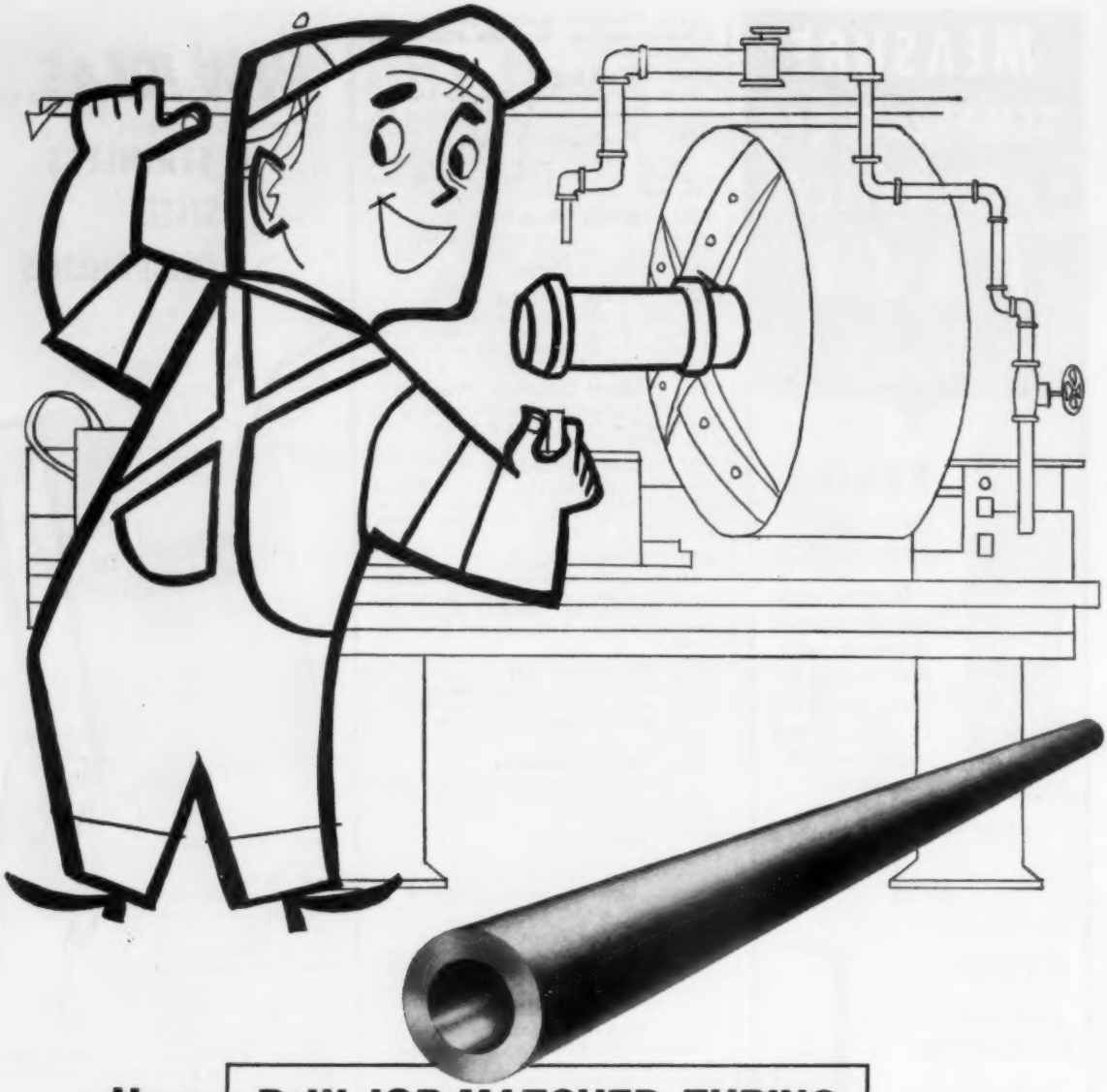

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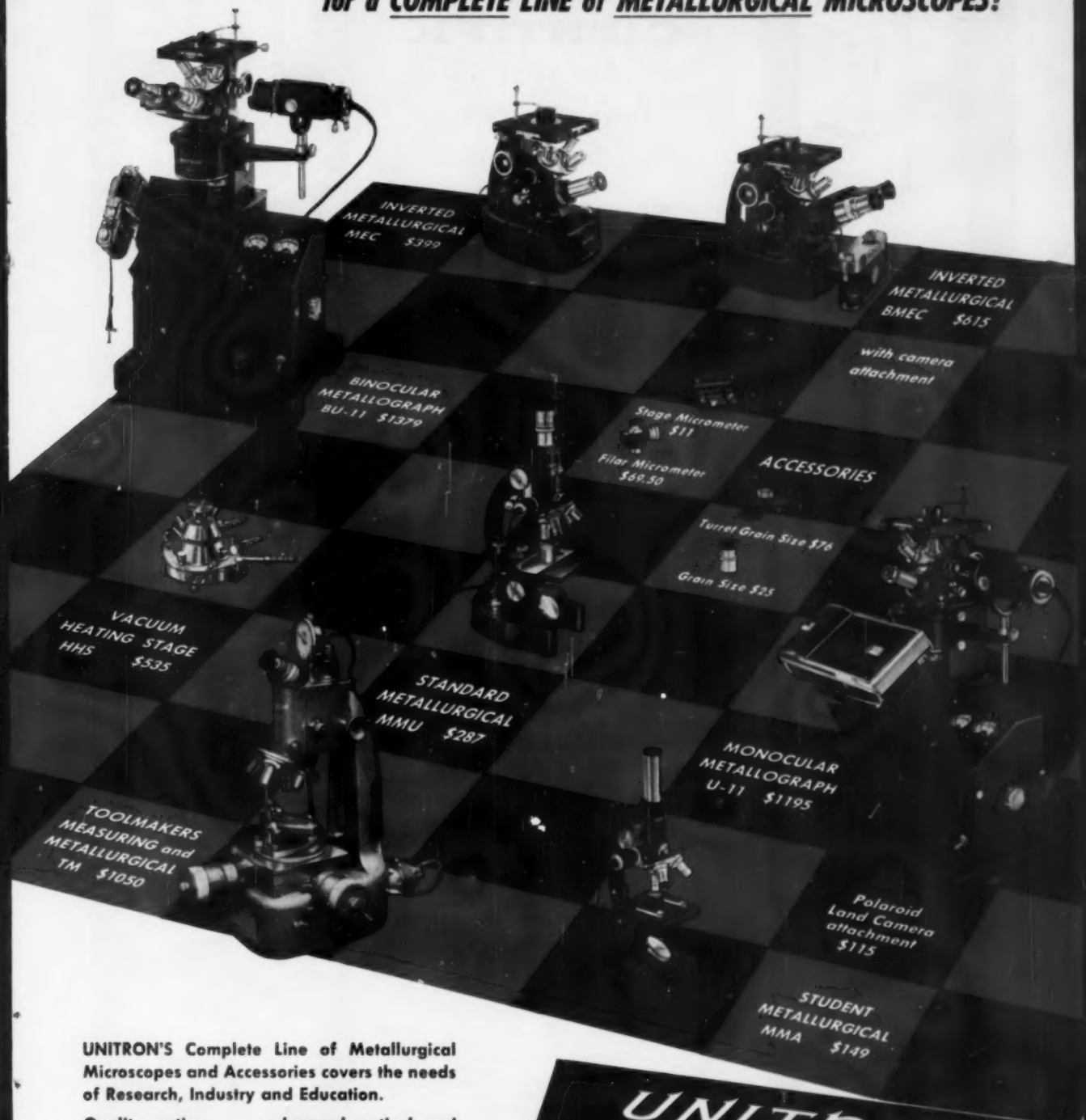

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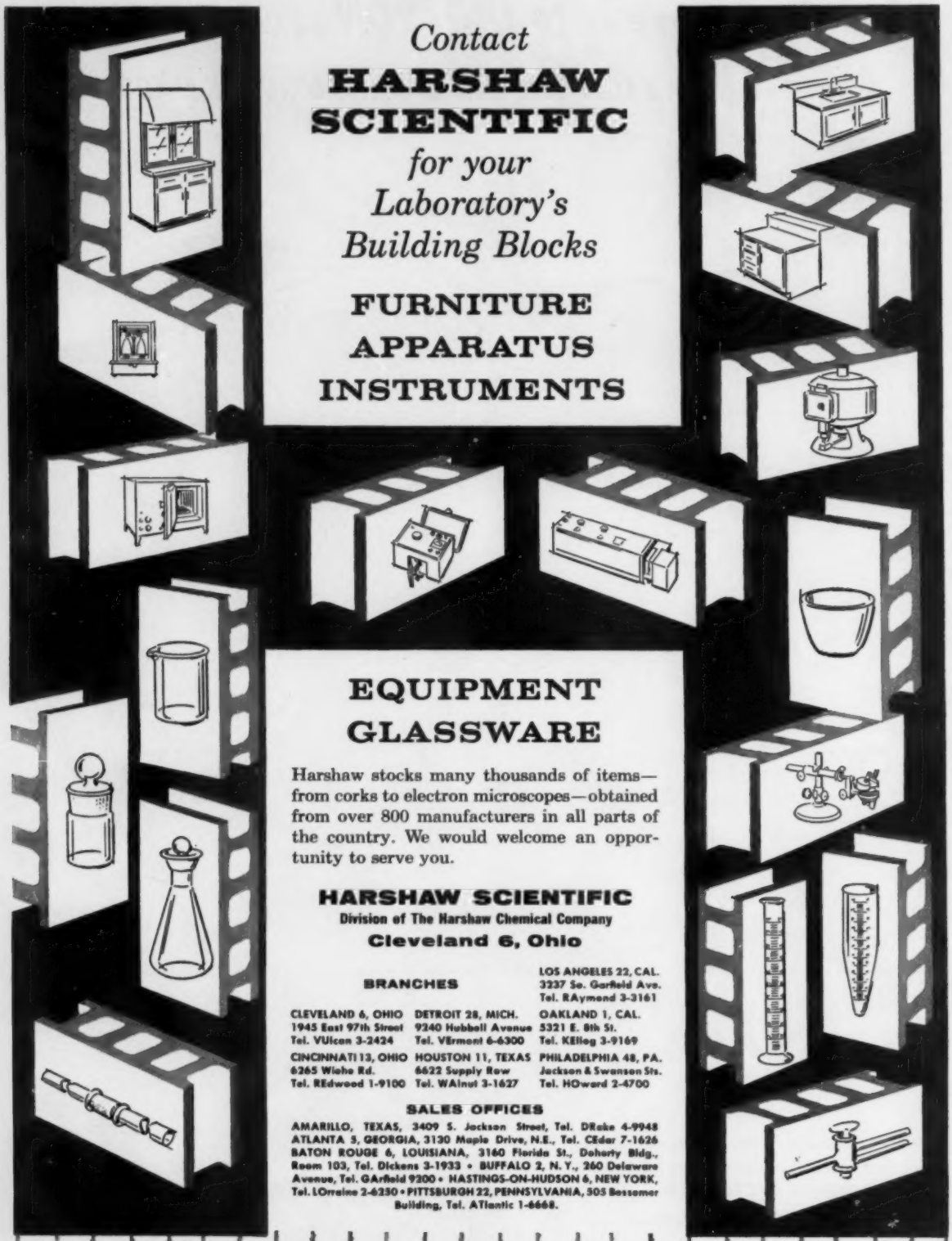

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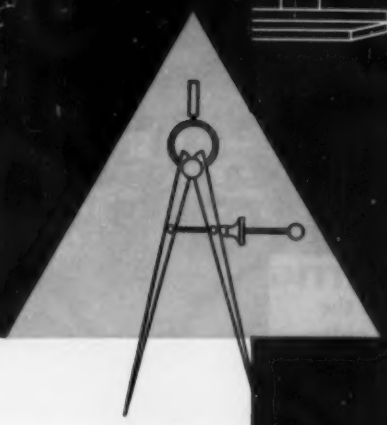

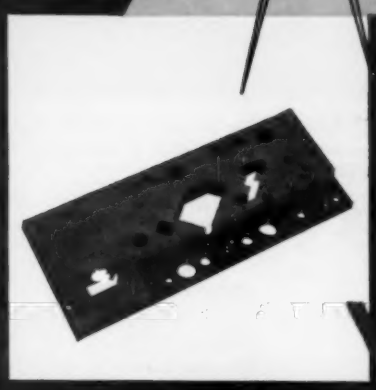

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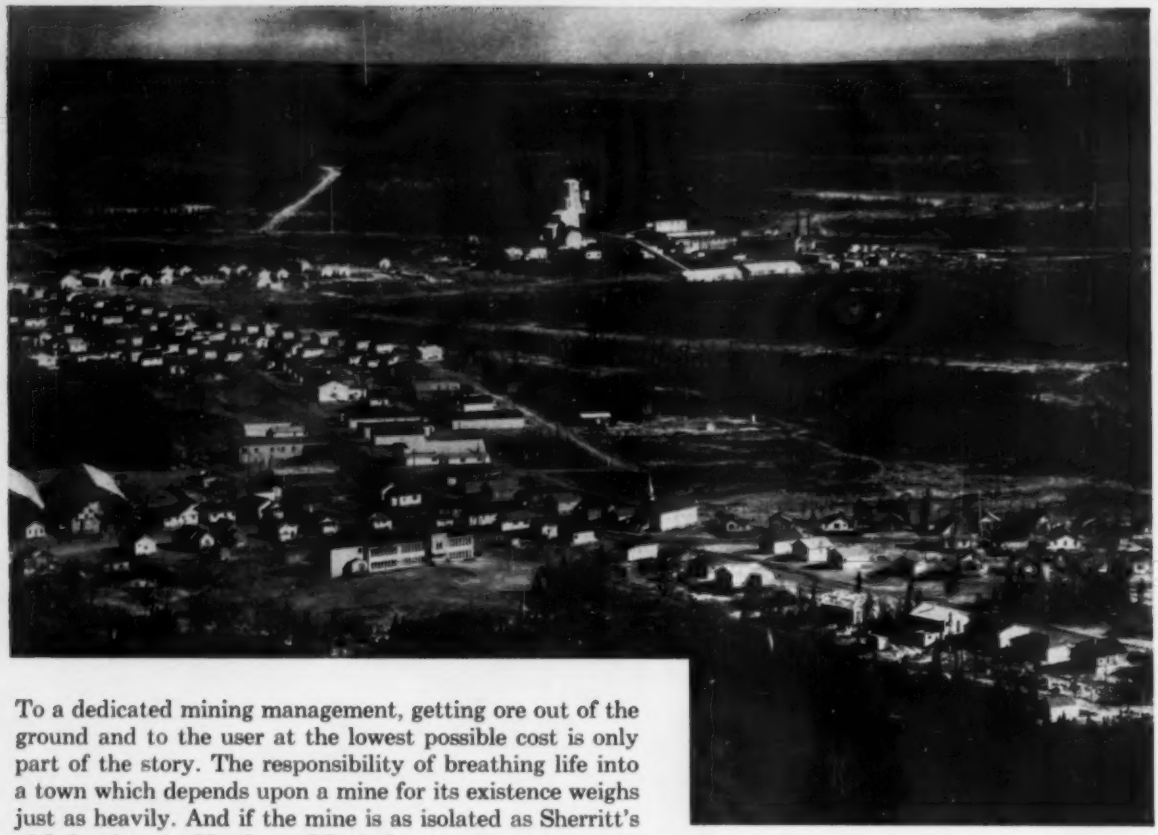

The Sherritt mines at Lynn Lake, Manitoba, yield a generous 2500 to 3500 tons of nickel-copper-cobalt ore per day.

To a dedicated mining management, getting ore out of the ground and to the user at the lowest possible cost is only part of the story. The responsibility of breathing life into a town which depends upon a mine for its existence weighs just as heavily. And if the mine is as isolated as Sherritt's nickel mine in Northern Manitoba, management must further provide all the tools the town needs to run itself happily . . . democratically . . . successfully.

Here at Lynn Lake a population of 2000 is supported by some 600 Sherritt people who work two nickel mines and a concentrating plant on a three-shift basis. But before this could be done, Sherritt had to move in all the facilities for an entire town . . . on tractor-pulled sleighs . . . over 165 miles of 20-degrees-below-zero wilderness. The great portage included 208 buildings—150 homes, a bank, a post office, a school, 2 churches—and a complete milling and concentrating plant. Two hydroelectric plants had to be built to provide power. And, later, a 150-mile railroad had to be built to handle the mines' output.

Today, Sherritt people at Lynn Lake turn out 2500 to 3500 tons of ore per day which is concentrated, then shipped to the company's refinery at Fort Saskatchewan 800 miles away. There it is refined to yield 35 tons of 99.8% pure nickel per day by people who also realize that getting the nickel out is only part of the job.

Getting the nickel out

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SHERRITT

FOOTE MINERAL COMPANY is the exclusive sales agent for Sherritt nickel and cobalt in the United States and Canada. For product literature, prices, and delivery information, contact the Foote Mineral Company, 424S Eighteen West Chelten Building, Philadelphia 44, Pennsylvania.

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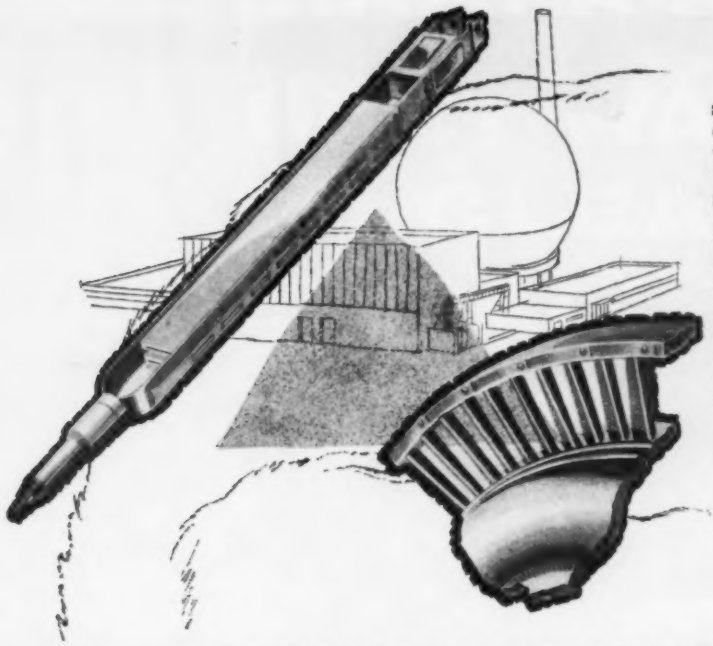

Today's metallurgical engineers and scientists are constantly meeting the challenge of sweeping technological advances. Electronic brains that solve "impossible" problems . . . jets and space craft which open brand-new horizons . . . reactors that produce fantastic amounts of nuclear energy. Advances such as these *demand* better metals . . . metals free of inclusions, with better electrical conductivity, increased hot strength, extended creep resistance and fatigue limits. In turn, better refractories are a "must" in order to precisely control purity and composition during the development of these metals.

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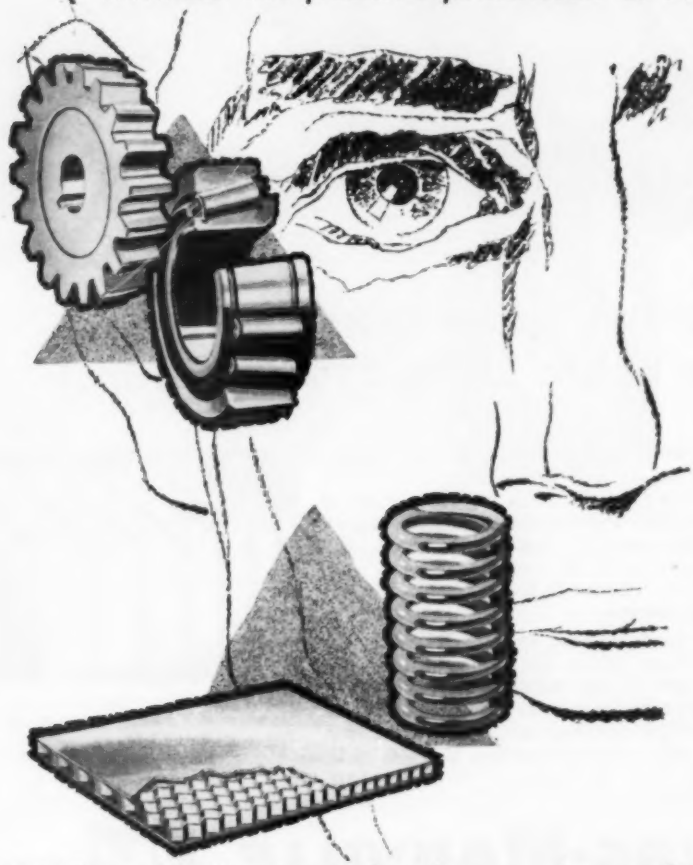

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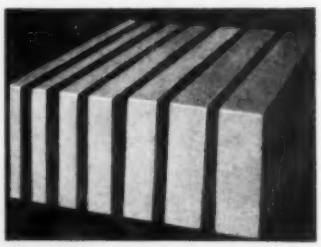

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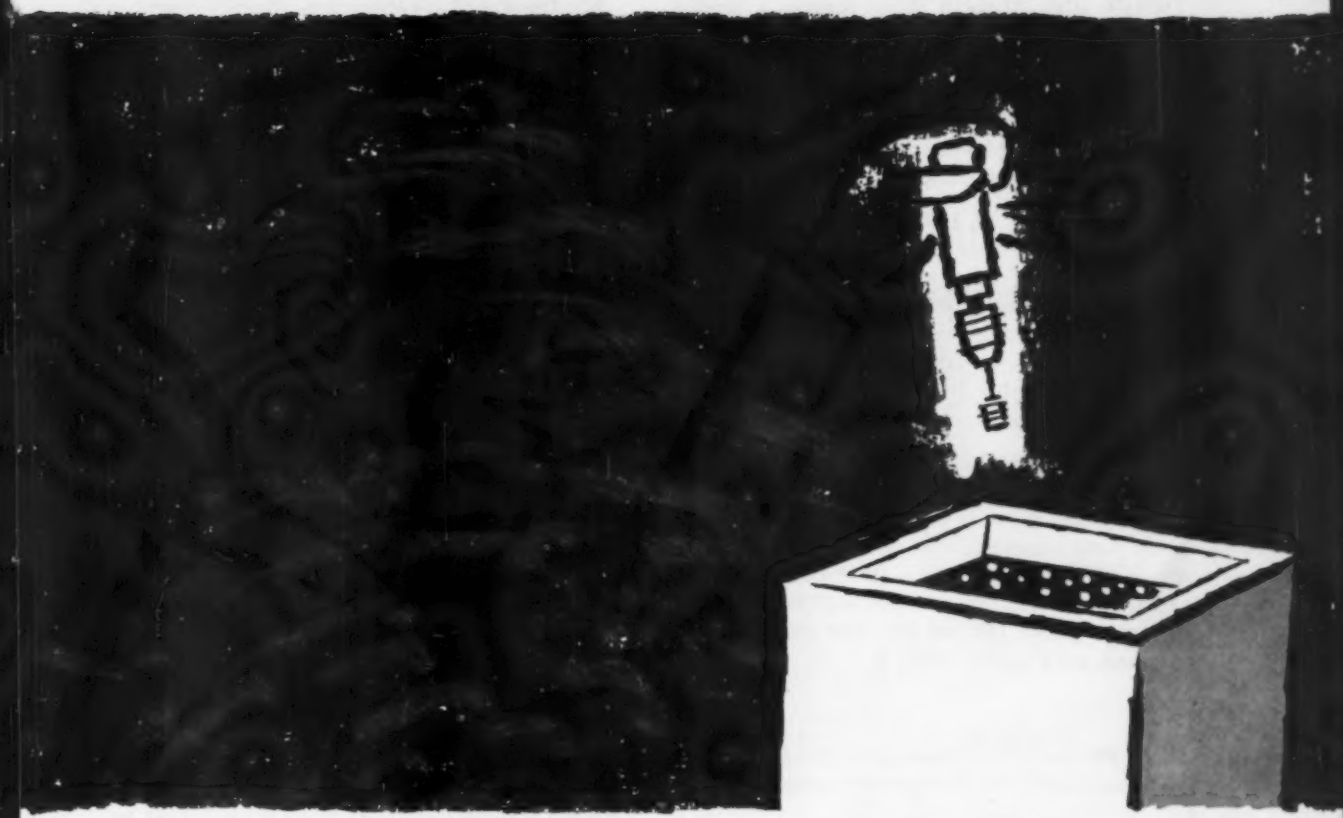

It's the Acoustica ultrasonic way! The metal is immersed in a cleaning solution, activated in an Acoustica ultrasonic tank. Almost instantaneously, the fluid bubbles with powerful "cavitational" action. *"Silent sound" is at work!* In seconds the dirt has disappeared—every particle of it, down to the invisible dust that escapes the human eye. *It has been blasted away ultrasonically!* There is no laborious, time-consuming scrubbing, no disassembling—maintenance costs are at a minimum. Results are better, faster, cheaper. Definitely the world's best way to clean metal is the Acoustica ultrasonic way!

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Today's ultra-strength steels possess a unique combination of mechanical properties even when they are used at their ultimate levels of tensile strength. One of the first steels developed in this class — Crucible HY-Tuf® — combines high impact strength, hardness and good ductility at the 220,000/240,000 psi range.

HY-Tuf (1.8% Ni, 1.30% Mn, 1.50% Si, 0.40% Mo) was first widely used in aircraft applications because of its favorable strength-weight ratio. But, because it is also tough and hard, it has rapidly found its way into power-driven garden tools, hand- and power-operated banding machines, rock bit bodies, cutter head bolts, couplings, pinion gears and shafts.

HY-Tuf's high impact strength, especially at high levels of tensile strength or hardness, has been demonstrated in a great number of tests. These tests prove HY-Tuf definitely superior to standard AISI alloy steels in impact strength and ductility at hardnesses above 42 Rc or tensile strengths above 190,000 psi. For specific comparisons, see Figures A and B.

FIG. A—TENSILE AND IMPACT DATA

Grade	Temper	Rc	Tensile Strength, psi	.2% Yield Strength, psi	.01% Yield Strength, psi	% Elong. in 2 in.	% Red. Area	Izod Impact Ft-Lb
HY-Tuf	550F	46.5	234,000	193,000	154,000	13.1	49.7	31
4340	700	46	228,000	212,000	210,000	11.2	47.8	17
4140	800	46	227,000	205,000	198,000	11.2	39.4	8
9442	700	46	225,000	203,000	200,000	10.3	43.4	11

Oversize .505" dia. tensile specimens and finish machined Izod specimens were oil quenched from the conventional austenitizing temperatures and tempered as indicated.

FIG. B—MAXIMUM IMPACT PROPERTIES
(at hardness of Rockwell C45 or greater)

Grade	Izod			Tension Impact			
	Ft-Lb	Temper	Rc	Ft-Lb	Elong.	Temper	Rc
HY-Tuf	33	400F	47.5	195	16	None	47.5
4340	13	860	45	158	12.2	400F	55
4140	17	500	52	160	14	375	55
8630	19	400	51	148	14	200	52.5
4130 (oil)	17	500	47.5	133	14.5	200	50
4130 (water)	21	450	50	142	13.0	200	52.5

The alloy's superior ductility is shown by these slow bend tests performed on ⅞" rod bars heat treated to 47 Rc.

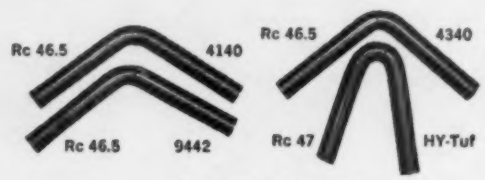

FIG. C—BEND TESTS
Bars — ⅞" rd.

HY-Tuf's notch sensitivity is much lower than that of conventional steels at hardnesses of 45 to 47.5 Rc. Unlike other alloys, HY-Tuf has higher impact values for the V-notch Izod test than for the keyhole Charpy test. This is important because it means that HY-Tuf is much less sensitive to a notch at high strength levels than ordinary steels.

Crucible HY-Tuf conforms to MIL-S-7108 and AMS 6418 and is available in commercial sizes and quantities. For more information on this ultra-strength alloy, send the coupon.

* *ultra-strength steel's impact strength, hardness*
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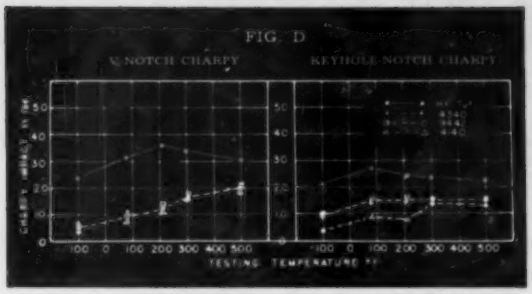

Effect of testing temperature on the notch impact values of HY-Tuf and conventional steels heat treated to 47 Rc.

New Low Prices of Titanium Mill Products Justify Using The Alloy in More Applications

Early this year Crucible's Titanium Division announced new price reductions for its titanium mill products – that cut these prices to *a new industry low*. The reductions, as much as 25%, affected both base prices and the costs of "extras".

For example, sheet was cut from $9.10 per pound base price to $7.75. Strip was reduced $1.25 per pound to $7.25. Plate, formerly $6 per pound, now costs only $5.25. Crucible also slashed billet prices to $3.55 per pound and wire to $5.75 per pound. Bar items were reduced $1.00 per pound to $4.25 (base price). In addition, some size "extras" were reduced as much as 55%, and finished "extras" by over 40%.

Because of these lower prices, engineers can now utilize titanium's unique properties in many more applications and justify the selection economically. (Even at previous prices, titanium often proved itself the low-cost metal on a cost-per-service-year basis.) This should prove especially true in processing applications requiring corrosion resistance and long-service life, and in aircraft and missile applications where high-strength, lightweight materials are essential.

During the past five years, titanium fabricating costs have also been cut substantially because of experience gained in forging, machining, welding and forming. ***For detailed information on Crucible titanium mill products, send the coupon.***

Permanent magnet handbook: 346 pages of design data

One of the most comprehensive manuals ever published on permanent magnets is available through Crucible Steel Company.

The *Permanent Magnet Handbook* contains all the data needed to design magnets into generators, meters, compasses, chucks, couplings, hi-fi and television components, and thousands of other products. It also contains entire sections on permanent magnet measurements, ferromagnetism, magnetization, demagnetization and electro-magnetic theory. It gives the complete performance and property data of over 60 different magnet materials: such as, magnet steels, Alnico alloys, and Ferrimag ceramics.

To cover actual printing costs, a nominal sum of $10.00 is being charged for each copy. However, this sum also covers the cost of additions to the handbook – mailed to subscribers each time new Crucible data become available.

For your copy, send the coupon and check or money order for $10.00. If you are located in Pennsylvania, add 35¢ for state sales tax.

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Dept. EJ09, The Oliver Building
Mellon Square, Pittsburgh 22, Pa.

Gentlemen:
Please send me the following:

1. Crucible HY-Tuf Data Sheet ☐
2. Further information on titanium mill products ☐
3. Permanent Magnet Handbook (Enclose check or money order) ☐

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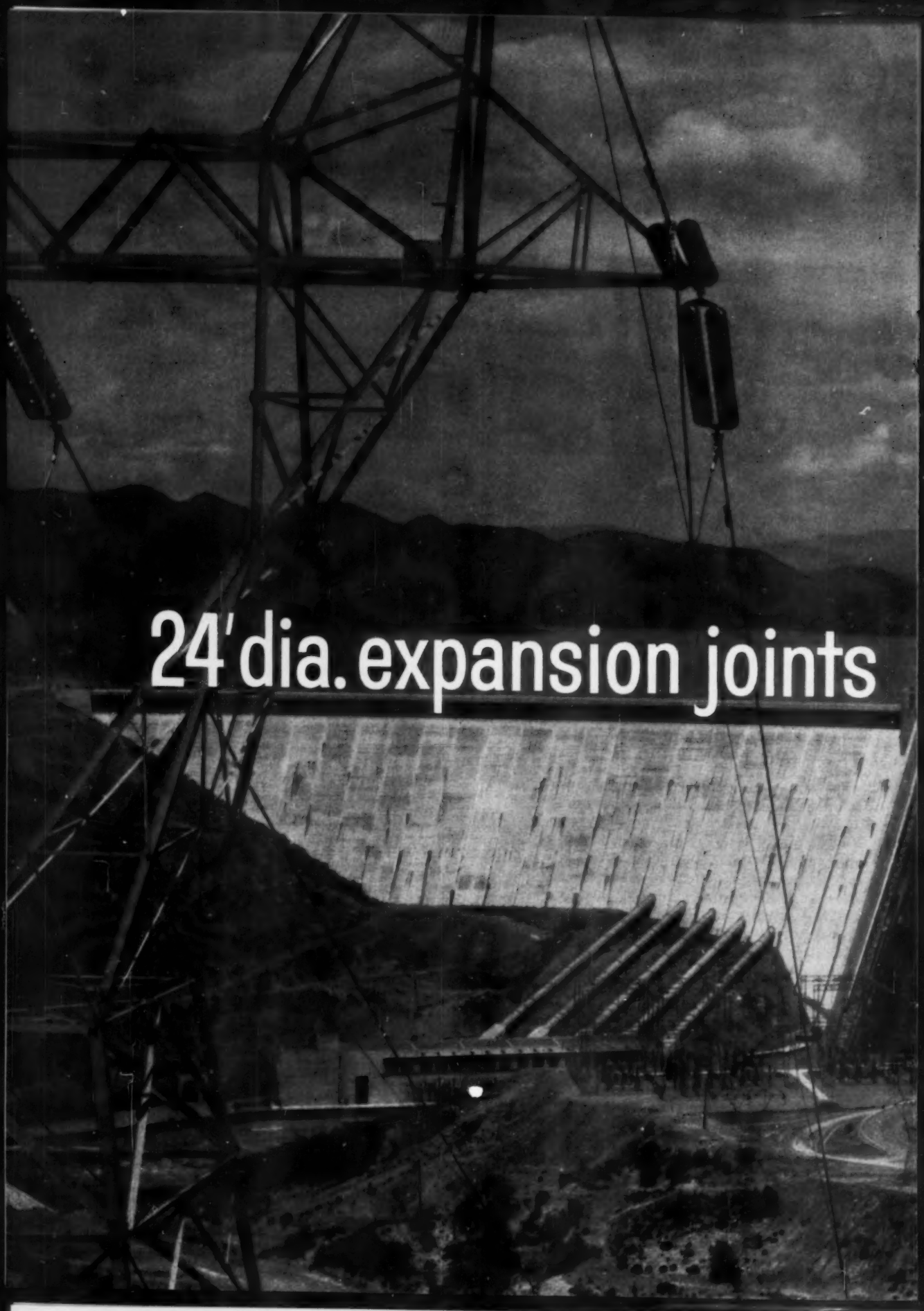
Title_____
Company_____
Street_____
City_____ Zone_____ State_____

CRUCIBLE STEEL COMPANY OF AMERICA


24' dia. expansion joints

Stainless steel expansion joints
for penstocks 24 feet in diameter
are no easy job for the fabricator.

It is a problem of fixturing,
metallurgy and welding.

Alert Steel Products Company
took the job and
were successful on the first try.

Before beginning to tool up,
Mr. Jules Davis, Alert's President,
called in the man
who specializes in welding problems—
the Lincoln Welding Engineer.

The Lincoln man, Tom Farris,
suggested submerged arc welding
with a "Mechanized Squirt"
18/8 wire and a special flux
for welding stainless—ST-100.

Then, Mr. Farris and Mr. Ed Klein,
Alert's Chief Engineer,
planned the fixturing to give
rigid support while welding.

fabricated in stainless

by Submerged Arc Welding

Result: On the first try
the 10,000-pound ring
(one-half of one joint)
was welded in eight separate pieces,
to give a total tolerance
of 1/16-inch upon assembly.

Tests found the weld structure perfect
and analysis as predicted.

If you have tough welding problems,
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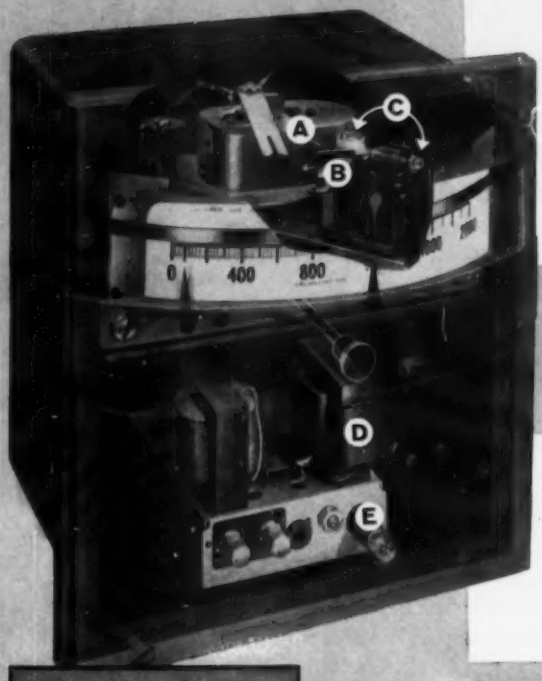
LINCOLN



MEASURING UNIT

A. A thermocouple signal to a d'Arsonval galvanometer, the only moving part, moves the indicating pointer up scale.

B. Aluminum vane adjusts the amount of light received by the photocell from the operating lamp.

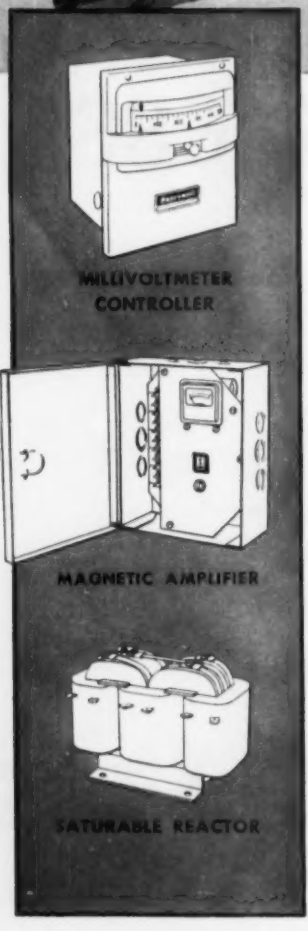
C. If operating lamp or photocell fails, output voltage assumes a value equal to high temperature.

***Pyr-O-Volt* has built-in voltage regulator to maintain voltage within ± 1% of level required for maximum operating stability. Spare operating lamp supplied. Thermocouple burnout protection optional. Available in horizontal and vertical case.**

CONTROL UNIT

D. A one-stage magnetic amplifier amplifies small current from the photocell in the measuring unit. This is the only active electronic element in the controller.

E. Pilot light goes out on line power failure.



For your electric heating applications . . .

Use this accurate, dependable *Pyr-O-Volt** controller

- **No tubes to wear out**
- **Voltage regulation**
- **Fail-safe design**
- **Contactless, stepless control**

Here's an accurate instrument for reliable stepless control of saturable reactors, r.f. generators and other power amplifiers. It has a proportional band adjustable from 2/3% to 5%, and a manual reset adjustment which shifts the control point over 100% of the proportional band.

The *Pyr-O-Volt* controller can control saturable core reactors up to 100 kva, if used with a Brown magnetic amplifier. You can also use this proportional output millivoltmeter-controller with the General Electric *Reactrol***, and with the Westinghouse *Furnatron*.*** Complete packaged systems available.

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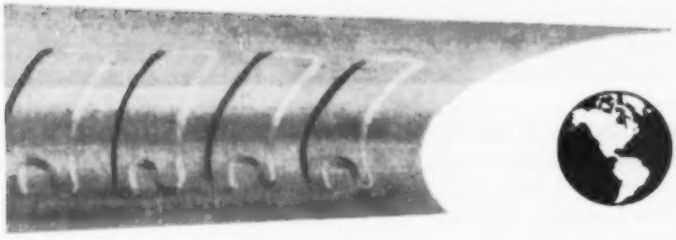

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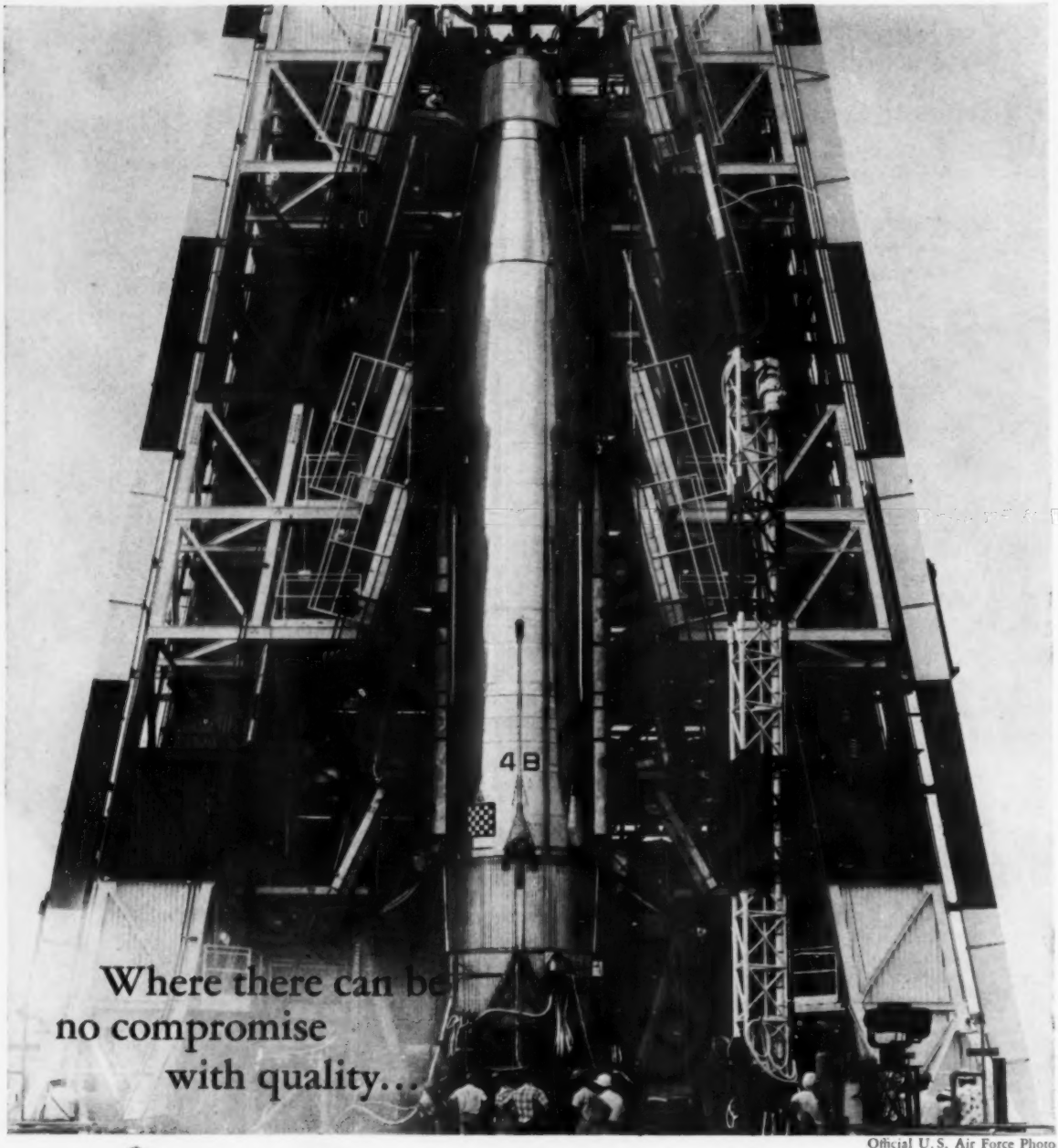

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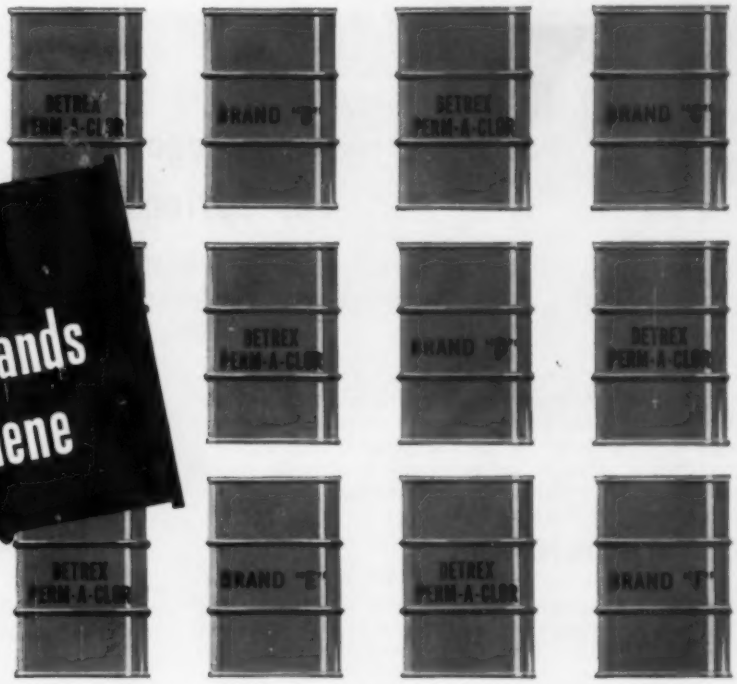

Sure-There Are Several Good Brands of Trichlorethylene

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Depend on DETREX for Every Metal Cleaning and Processing Need

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- Ultrasonic Equipment
- Industrial Washers
- Phosphate Coating Compounds
- PAINTBOND Compounds
- Aluminum Treating Compounds
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When DETREX pioneered solvent degreasing and introduced PERM-A-CLOR, more than a quarter of a century ago, it completely revolutionized metal cleaning. Today's PERM-A-CLOR is the finest of trichlorethylene products – the result of years and years of testing and proving, in the laboratory and on the job.

Combine PERM-A-CLOR with DETREX tailored-to-the-job equipment, and even greater efficiencies are realized. Operating costs are reduced, worker productivity is increased, more parts are cleaned per pound of solvent.

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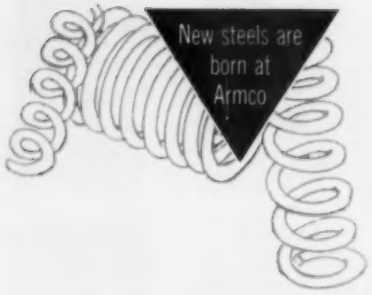

Advantages of 17-7 PH Stainless Steel For Springs in Severe Service

Excellent elastic properties, strength at high temperatures, resistance to corrosion—all are combined in Armco 17-7 PH Stainless Steel wire to make it an outstanding material for springs operating under severe conditions.

Armco 17-7 PH is one of a family of Armco Precipitation-Hardening Stainless Steels developed to meet the exacting needs of space age technology. For springs it offers a unique combination of properties that make it especially useful in applications involving heat or corrosion, where ordinary spring materials don't hold up.

EXCELLENT ELASTIC PROPERTIES

In tension, the elastic limit of 17-7 PH wire is approximately 75% of ultimate tensile strength; in torsion, about 55%. The figures in Table 1 give an idea of the excellence of these values. See table 2 for a comparison with 18-8 stainless and music wire. Relaxation and torsional modulus values of 17-7 PH stainless hold at high levels even at temperatures up to about 650 F.

TABLE 1

Typical Room Temperature Properties of .052 to .061-inch 17-7 PH Wire

CONDITION	PROPERTIES			
	UTS, psi	0.2% Yld. Str., psi	Elong. in 2", %	Fatigue Str. * % of Tens. Str. at 10^7 Cycles
C	250-280,000	230-260,000	—	—
CH 900	305-335,000	285-315,000	2-4	36

*Machined and polished surfaces

TABLE 2

Comparison of Typical Mechanical Properties of Armco 17-7 PH Condition CH 900 Wire, 18-8 Spring Wire and Music Wire

	17-7 PH	18-8	MUSIC WIRE
Diameter, Inches	Ultimate Tensile Strength, 1000 psi		
.030	320-350	280-310	340-365
.093	279-309	230-260	285-305
.148	256-286	201-231	263-280
.192	252-282	185-215	252-267
Diameter, Inches	Max. Torsional Stress When Closed Solid, 1000 psi		
.050	170	113	160
.100	160	100	140
.150	155	93	130
.200	150	87	—

CORROSION RESISTANCE

Armco 17-7 PH Stainless Steel extends the dependability of springs beyond that of metals with comparable strength but inferior resistance to corrosion. In Condition CH 900, for example, the condition most widely used for wire products, 17-7 PH resists corrosion as well as 18-8 full-hard temper stainless steel. Even in a marine atmosphere, 2 years' exposure produces only superficial rusting.

SPRING FABRICATION

Availability of 17-7 PH round or flat wire, coils or straight lengths, and a wide range of sizes and conditions, makes it adaptable to the production of a great many kinds of springs.

It's workable as well. In Conditions C and CH 900, for example, 17-7 PH wire can be wrapped on its own diameter. However, because Condition C is more ductile, it is preferred for spring coiling, especially on automatic machines.

The low-temperature precipitation hardening of 17-7 PH after fabrication takes care of stress relieving too. No further heat treatment is required as with other hardenable spring materials. Thus a production operation is eliminated and the possibility of dimensional changes is avoided. Also, because no heavy scale is produced and because plating is not necessary, 17-7 PH springs are not exposed to hydrogen-absorbing conditions. A very light pickle will remove heat tint.

SEND COUPON FOR DATA

For more information on Armco 17-7 PH Stainless Steel or its special precipitation hardening companion grades, 17-4 PH and PH 15-7 Mo, just fill in and mail the coupon. There's no obligation.

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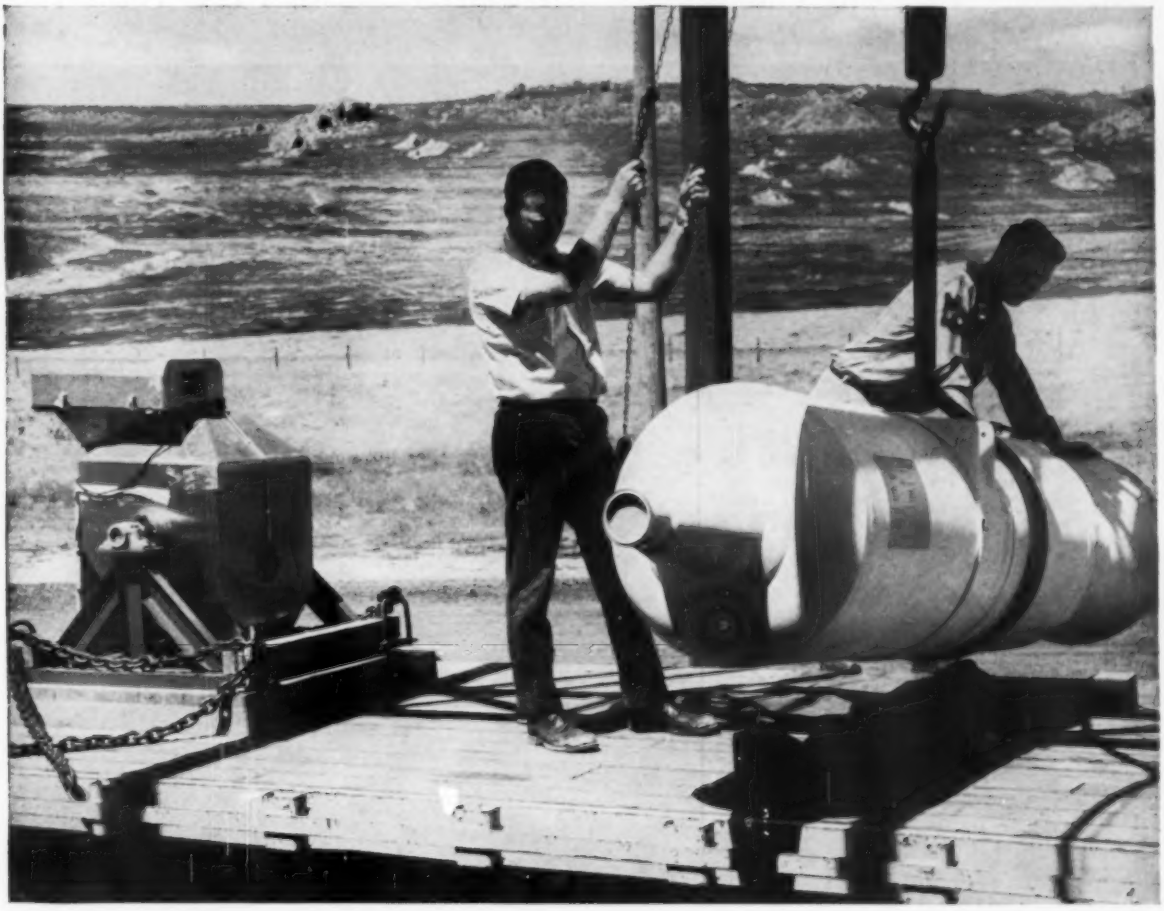

COBALT 60 AND THE MATADOR

Thiokol Chemical Corporation, Utah Division, chose Nuclear Systems' Model 1060 Multitron with a 1,000 curie cobalt 60 source for routine radiography of the Matador engine. The radiographs obtained provide non-destructive testing information which has greatly increased the reliability of the rocket. This unit, along with several others, has been used continuously by Thiokol for the inspection of solid propellants for over a year.

Nuclear Systems offers the most complete line of gamma radiography equipment for this and many other applications.

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How Ryerson helped Stainless buyer solve missile component problem

Titanium stringers in stainless forged bars were recently creating a difficult problem for a manufacturer of missile parts. This company's first step in solving the problem: call in a Ryerson representative.

Selection of the wrong type of stainless was found to be the cause of the trouble. The Ryerson man pointed out that stringers are inherent in Type 321 stainless then being used. He recommended switching to Type 347 stainless. Result: the same stabilized corrosion resistance and strength—but no titanium stringers.

This is just one more example of value-analysis teamwork between manufacturers across the country and Ryerson specialists—a close association that increases the value of their metal-buying dollars. Put Ryerson on *your* value-analysis team. A discussion with your Ryerson I.V.B.M. specialist will show how you can get Increased Value in Buying Metals from Ryerson.

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Come to Chicago...

A GREAT INDUSTRIAL DRAMA will unfold the first week in November when management men and technical leaders of the metalworking industry gather in Chicago for the 41st National Metal Congress and Exposition. Six other societies are cooperating with the American Society for Metals to make this one of the most outstanding technical and engineering programs of recent years. In the Metal Exposition, more than 375 firms (p. 89) will demonstrate ways to make products better and cheaper. Visitors will be able to get information and locate products on specific metalworking problems in the great, one-level exposition hall.

More than 50 outstanding papers on the science of metals have been selected by the ASM *Transactions* Committee for presentation (digests of some of these start in p. 170). Woodside Memorial panel conferences will concentrate on engineering developments with discussions on composite materials, refractory metals, explosive forming and other fabricating techniques. Two additional A.S.M. events are a seminar, set for Oct. 31 and Nov. 1, presenting 12 timely papers on Resonance and Metal Relaxation, and a two-day meeting, jointly planned with the Atomic Energy Commission, on rare earth metals.

The fall meeting of the Metallurgical Society of A.I.M.E. will sponsor meetings for four days – Nov. 2 to 5. The Society for Nondestructive Testing has a full program which includes an educational clinic and other sessions on technical topics. The Ultrasonic Manufacturers Association (a newly cooperating group) is sponsoring a session on ultrasonics in metalworking. The Metal Powder Industries Federation, in cooperation with Powder Metallurgy Parts Manfacturers Association, will feature a clinic on parts. The Metal Treating Institute will conduct a panel discussion on heat treating gears. The Metals Division of Special Libraries Association also has a special program planned.

In the following pages a detailed program is arranged day by day to assist the visitor in choosing the features of most interest. To complement the events of metal month, the editors of *Metal Progress* bring you in this issue specially planned articles to help you do a better job in metal selection and production to meet rising costs in the metalworking industry. Built around the theme "Overcoming the Producibility Barrier", features are presented in three parts: use of improved metal forming techniques (p. 97), more suitable selection of everyday metals (p. 129) and better use of atmospheres in heat treating and metal processing (p. 146).

Come to the National Metal Congress and Exposition. Benefits will be in the form of greater knowledge of materials and manufacturing methods. You can use this information not only in the exotic applications for metals but also to improve the more prosaic things made of metals – like furnaces, machine tools, hardware and household appliances, automobiles and business machines. You can be sure your alert competitors will be there.

Clarence H. Lorig

CLARENCE H. LORIG, *President*
AMERICAN SOCIETY FOR METALS

41st National Metal Congress and Exposition

Chicago, Oct. 31 through Nov. 6, 1959

American Society for Metals ..... **Headquarters, Sherman Hotel**

Seminar on Resonance and Relaxation in Metals, Saturday and Sunday
Technical Sessions, Monday morning through Thursday afternoon
Metals Engineering Panel Discussions, Monday morning through Wednesday afternoon
Symposium on the Rare Earths and Related Metals (in Cooperation With U. S. Atomic Energy Commission), Monday and Tuesday
Honors and Awards Luncheon, Tuesday noon
Annual Meeting and Campbell Memorial Lecture, Wednesday morning
Annual Banquet, Thursday evening
National Metal Exposition, Monday through Friday (Public Auditorium)

Fall Meeting of the Metallurgical Society of A.I.M.E., Sponsored by the Institute of Metals Division ..... **Headquarters, Morrison Hotel**

Committee Meetings, Sunday through Thursday
Technical Sessions, Monday morning through Thursday
Powder Metallurgy Special Luncheon, Tuesday noon
Annual Fall Dinner, Tuesday evening

Society for Nondestructive Testing ..... **Headquarters, Hotel Hamilton**

Educational Clinic, Friday all day
Technical Sessions, Monday through Thursday
Annual Luncheon, Wednesday noon
Annual Meeting and Lester Honor Lecture, Wednesday afternoon

Metal Treating Institute ..... **(Jointly With ASM)**

Technical Session, Thursday afternoon

Metal Powder Industries Federation and Powder Metallurgy Parts Manufacturers Association ..... **(Jointly With ASM)**

Technical Session, Wednesday afternoon

Ultrasonic Manufacturers Association ..... **(Jointly With ASM)**

Technical Session, Thursday morning

Special Libraries Association, Metals Division
Headquarters, LaSalle Hotel

Sessions and Inspection Trips, Thursday and Friday
Banquet, Thursday evening

Complete programs, grouped by days, on following pages

Saturday October 31, 1959

9:00 A.M. Sherman Hotel

Seminar on Resonance and Relaxation in Metals

Acoustic and Magnetic Resonance
By *Arthur S. Nowick*, International Business Machines Research Center

Cycolotron Resonance in Metals
By *John K. Galt*, Bell Telephone Laboratories

Nuclear Resonance in Metals at Low Fields
By *Alfred G. Redfield*, International Business Machines, Watson Laboratory

2:00 P.M. Sherman Hotel

8:00 P.M. Sherman Hotel

Seminar on Resonance and Relaxation in Metals

Ferromagnetic Resonance
By *Donald S. Rodbell*, General Electric Research Laboratory

Relation of Metallic Bonding to Elastic Constants
By *C. S. Smith*, Case Institute of Technology

Dislocation Relaxation at High Frequencies
By *P. G. Bordoni*, University of Pisa (Italy)

Sunday November 1, 1959

9:00 A.M. Sherman Hotel

2:00 P.M. Sherman Hotel

Seminar on Resonance and Relaxation in Metals

Elastic Internal Friction Effects in Crystals and Dislocations
By *James S. Koehler*, University of Illinois

Large Amplitude Effects and Fatigue
By *W. P. Mason*, Bell Telephone Laboratories

Investigation of Radiation Damage Using Acoustics
By *David K. Holmes*, Oak Ridge National Laboratories

Stress-Induced Atom Motion
By *Charles A. West*, University of Illinois

Interaction of Conduction Electrons and Acoustic Waves
By *Donald F. Gibbons*, Bell Telephone Laboratories

Investigation of Metallurgical Phenomena Through Elastic Constants
By *John M. Sivertsen*, University of Minnesota

Monday Morning
November 2, 1959

9:00 A.M. Sherman Hotel

Steel—I

Effect of Cold Work on Temper Brittleness
By *A. S. Keh* and *W. C. Porr*, U. S. Steel Corp. Research Center

Influence of Static Stress and Temperature on Internal Damping
By *J. W. Clark* and *W. C. Hagel*, General Electric Co.

Correlation Between Internal Friction and Temper Brittleness in Steel
By *A. F. K. Kaddou* and *P. C. Rosenthal*, University of Wisconsin

Gas-Metal Reactions During Box Annealing of Low-Carbon Steel
By *R. M. Hudson* and *G. L. Stragand*, U.S. Steel Corp. Research Center

Importance of Directionality in Drawing Quality Sheet Steel
By *R. L. Whiteley*, Bethlehem Steel Co.

9:00 A.M. Sherman Hotel

Titanium

Anomalous Effect of Hydrogen on the Mechanical Properties of Ti With 8% Mn
By *A. H. Fleitman*, Crane Co. Engineering Division

Supersaturation as a Factor in the Hydrogen Embrittlement of Titanium Alloys
By *D. N. Williams, F. R. Schwartzberg* and *R. I. Jaffee*, Battelle Memorial Institute

Diffusion of Oxygen in Alpha and Beta Titanium
By *W. P. Roe*, American Smelting and Refining Research Laboratories, *H. R. Palmer*, Titanium Metals Corp. of America and *W. R. Opie*, National Lead Co. Research Laboratory

Kinetics of Decomposition of Alpha Prime in a Ti-Cu Alloy
By *M. P. Gomez*, Boeing Airplane Co. and *D. H. Polonis*, University of Washington

Aging Behavior of the Alloy Ti, 6Al, 4V
By *J. M Dupouy, M. B. Bever* and *B. L. Averbach*, Massachusetts Institute of Technology

Corrosion Behavior of Titanium-Palladium Alloy
By *M. Stern* and *C. R. Bishop*, Union Carbide Metals Co.

9:00 A.M. Sherman Hotel

First Metals Engineering Panel Conference on Composite Metals

Precision and Specialty Composite Metals
By *J. J. Buchinski*, Metals and Controls Division of Texas Instruments, Inc.

Vacuum Coated Composites
By *Howard M. Farrow*, NBC Equipment Corp., and *Philip J. Clough*, National Research Corp.

Clad Metals
By Louis K. Keay, Lukens Steel Co.

9:00 A.M. Sherman Hotel

ASM-AEC Symposium on the Rare Earths and Related Metals
I—Occurrence and Extraction

General Introduction
By *R. R. Nash*, Division on Research, Atomic Energy Commission

Historical Introduction
By *F. H. Spedding*, Iowa State University

Chemistry of the Rare Earths
By *Therald Moeller*, University of Illinois

Occurrence and Strategic Supply
By *R. J. Anderson*, Battelle Memorial Institute

Separation by Fractional Crystallization
By *Howard E. Kremers*, Lindsay Chemical Division, American Potash and Chemical Co.

Separation by Liquid-Liquid Extraction
By *D. F. Peppard*, Argonne National Laboratory

Separation by Ion Exchange
By *J. E. Powell*, Iowa State University

9:00 A.M. Ballroom, Morrison Hotel

Kinetics of Phase Transformations—I

Kinetics of Martensitic Transformations
By *Larry Kaufman*, Manufacturing Laboratories, Inc.

Kinetics of Ordering
By *L. R. Weisberg*, Radio Corp. of America

Kinetics of Precipitation
By *David Turnbull*, General Electric Co.

9:00 A.M. Constitution Room, Morrison Hotel

Symposium on Refractory Metals—I

Electron Beam Melting of Refractory Metals
By *Charles Hunt* and *H. R. Smith, Jr.*, Temescal Metallurgical Corp.

Purification Reactions of Tantalum During Vacuum Sintering
By *W. E. Klopp, D. J. Maykuth, H. B. Ogden* and *R. I. Jaffee*, Battelle Memorial Institute

Shape Casting of Molybdenum
By *E. D. Calvert, S. L. Ausmus* and *R. A. Beall*, U.S. Bureau of Mines

Consumable Arc Melting of Columbium-Base Alloys
By *T. L. Robertshaw* and *D. L. Keller*, General Electric Co.

9:00 A.M. Cotillion Room, Morrison Hotel

Research Abstracts on Diffusion

Self-Diffusion in Alpha Iron
By *C. E. Birchenall* and *R. J. Borg*, Princeton University

Diffusivity of Hydrogen in Alpha Iron
By *D. C. Carmichael*, Battelle Memorial Institute, *J. R. Hornaday, Jr.*, General Motors Corp., *A. E. Morris*, U.S. Bureau of Mines and *N. A. Parlee*, Purdue University

Solubility and Diffusivity of Hydrogen in Iron
By *M. L. Hill* and *E. W. Johnson*, Westinghouse Electric Corp.

Thermal Diffusion of Carbon in Alpha and Gamma Iron
By *Paul Shewmon*, Carnegie Institute of Technology

Determinations of the Diffusion of Chromium by Autoradiographic Techniques
By *H. W. Paxton, Tatsuro Kunitake* and *E. J. Pasierb*, Carnegie Institute of Technology

Electron Microprobe Measurements of the Diffusion of Columbium
By *L. S. Birks* and *R. E. Seebold*, U.S. Naval Research Laboratory

Diffusion of Uranium and Aluminum-Silicon Eutectic Alloy
By *D. R. Green*, General Electric Co.

Prediction of Electric Mobilities in Molten Alloys
By *E. E. Hucke*, University of Michigan

The Theory of Self-Diffusion in Liquid Metals
By *R. A. Swalin*, University of Minnesota

Solute Diffusion in Liquid Tin
By *C. H. Ma* and *R. A. Swalin*, University of Minnesota

9:00 A.M. Embassy Room, Morrison Hotel

Research Abstracts on Metal Processing

Progressive Solidification Study for Vacuum Cold Hearth Melting
By *J. H. Kelley, G. Facaros* and *B. W. Swanson*, Westinghouse Electric Corp.

Directional Freezing of Magnesium Alloys
By *A. S. Yue* and *J. B. Clark*, Dow Chemical Co.

Effects of Arc-Melting Conditions on Reactor-Grade Zirconium Alloy Ingots
By *J. H. Hart*, Westinghouse Electric Corp.

Use of Vibration in the Solidification of High-Temperature Alloys
By *L. M. Bianchi, J. H. Kelley* and *D. R. Carnahan*, Westinghouse Electric Corp.

An Effect of Ultrasonic Irradiation During Ingot Solidification
By *W. A. Tiller, D. H. Lane* and *J. W. Cunningham*, Westinghouse Electric Corp.

Melting Procedures as Related to Ingot Solidification
By *D. R. Carnahan* and *L. M. Bianchi*, Westinghouse Electric Corp.

An Investigation of Metal Spinning
By *S. Floreen, D. V. Ragone, E. E. Hucke* and *W. Steurer*, University of Michigan

Determining the Drawing Quality of Sheet by the Hydraulic Bulge Tester
By *W. N. Lambert, E. S. Madrzyk* and *F. E Gibson*, Inland Steel Co.

A New Method for Compacting Metal Powders Into Continuous Sections
By *Frank Emley* and *Charles Deibel*, Westinghouse Electric Corp.

9:00 A.M. Hotel Hamilton

First Session on New Instrumentation and Techniques

Product Reliability Through Nondestructive Testing
By *K. E. Cochran* and *H. T. Gruber*, Battelle Memorial Institute

Radioactive Magnetic Particle Inspection
By *Herbert E. Farmer*, General Electric Co.

Automatic Processing in Industrial Radiography
By *A. H. Allard* and *William D. Kiehle*, Eastman Kodak Co.

Radiography With the Electron Linear Accelerator
By *Samuel A. Wenk*, Applied Radiation Corp.

Report on "ADC"—a New Technique for Improving Accuracy of Eddy Current Flaw Detectors
By *Richard Hochschild*, Metrol Inc.

Field Distribution During Prod Magnetization
By *R. W. Gruetzmacher* and *Glenn O. McClurg*, Magnaflux Corp.

Monday Morning

10:00 A.M. International Amphitheatre

41st Annual Metal Exposition Opens

Monday Afternoon November 2, 1959

2:00 P.M. Sherman Hotel

High-Strength Steels

Fatigue Properties of High-Strength Steels
By *H. E. Frankel* and *J. A. Bennett*, National Bureau of Standards, and *W. A. Pennington*, University of Maryland

Influence of Pre-Existing Sharp Cracks on Brittle Fracture of a Ni-Mo-V Forging Steel
By *E. T. Wessel*, Westinghouse Electric Corp. Research Laboratories

Effect of Deformation Prior to Transformation on the Mechanical Properties of 4340 Steel
By *E. B. Kula* and *J. M. Dhosi*, Watertown Arsenal

Dimensional Stability of a Precision Ball Bearing Material
By *E. B. Mikus*, Convair Astronautics, *J. M. Gerty*, *T. J. Hughel* and *A. C. Knudsen*, General Motors Technical Center

Strength of Martensite Formed From Cold Worked Austenite
By *J. C. Shyne*, *V. F. Zackay* and *D. J. Schmatz*, Ford Motor Co. Scientific Laboratory

2:00 P.M. Sherman Hotel

Second Metals Engineering Panel Conference on Composite Metals

Laminated Metal and Ceramic Composite Materials
By *F. R. Shanley*, University of California, Los Angeles

Fiber Reinforced Metallic Composites
By *Robert W. Jech*, National Aeronautics and Space Agency

Metal Reinforced Ceramics
By *Joseph W. Chambers*, Marquardt Aircraft Co.

Vinyl-Coated Metals
By *Edward B. Osborne*, B. F. Goodrich Chemical Co.

2:00 P.M. Sherman Hotel

A.S.M.-A.E.C. Symposium on the Rare Earths and Related Metals

II—Applications of Metals and Compounds

Non-Nuclear Applications to Magnesium
By *T. E. Leontis*, Dow Chemical Co.

Non-Nuclear Applications to Ferrous and Other Light Metals
By *John F. Collins, V. P. Calkins* and *J. A. McGurity*, General Electric Aircraft Nuclear Propulsion Department

Non-Nuclear Applications to Nonmetallic Items
By *Howard E. Kremers*, Lindsay Chemical Division, American Potash and Chemical Co.

Nuclear Applications
By *Kermit Anderson*, Knolls Atomic Power Laboratory

Analytical Chemistry of the Rare Earths
By *C. V. Banks*, Ames Laboratory, Iowa State University

Analytical Spectroscopy of the Rare Earths
By *V. A. Fassel*, Ames Laboratory, Iowa State University

2:00 P.M. Embassy Room, Morrison Hotel

Research Abstracts on Thermodynamic and Physical Properties of Metals

Close-Packed Ordered Structures in Binary AB_3 Alloys of Transition Elements
By *A. E. Dwight*, Argonne National Laboratory, and *P. A. Beck*, University of Illinois

Crystal Structure of $MoNi_3$
By *Shozo Saito* and *P. A. Beck*, University of Illinois

Application of Gibbs-Duhem Equations to Multicomponent Systems
By *N. A. Gokcen*, University of Pennsylvania

The Magnesium-Iron System
By *A. S. Yue*, Dow Chemical Co.

Uranium-Molybdenum Phase Diagram Below 900°
By *A. E. Dwight*, Argonne National Laboratory

Transformations in Uranium-Fissium Alloys
By *S. T. Zegler* and *M. V. Nevitt*, Argonne National Laboratory

Lattice Parameters of Zirconium-Oxygen Solid Solutions
By *B. D. Lichter*, U.S. Air Force

Lattice Expansion of Rhenium and Titanium
By *J. I. Medoff* and *I. Cadoff*, New York University

Propagation of Sound in Liquid Hg-Tl Alloys
By *Gerald Abowitz* and *R. B. Gordon*, Yale University

Influence of Lattice Defects on Superconductivity of Tantalum
By *D. P. Seraphim, W. B. Ittner* and *D. T. Novick*, International Business Machines Corp.

Superconductivity of Dilute Interstitial Alloys of Tantalum with Hydrogen, Nitrogen and Oxygen
By *D. T. Novick, J. I. Budnick* and *D. P. Seraphim*, International Business Machines Corp.

2:00 P.M. Cotillion Room, Morrison Hotel

Research Abstracts on Creep and Fatigue

Effect of Stress on the Creep Rate of a Magnesium Crystal at 78 to 364° K.
By *Hans Conrad* and *L. Hays*, Westinghouse Electric Corp.

Origin of Tertiary Creep in an Aluminum Alloy
By *A. S. Nemy* and *F. N. Rhines*, Thompson Ramo Wooldridge, Inc.

Effect of Dilute Copper Alloying on Creep of Aluminum Single Crystals
By *D. Walton* and *L. Shepard*, General Dynamics Corp., and *J. E. Dorn*, University of California

Creep of a Recrystallized Aluminum SAP-Type Alloy
By *G. S. Ansell* and *F. V. Lenel*, Rensselaer Polytechnic Institute

Creep-Rupture of Alloys Near Their Melting Temperatures
By *M. Korchynsky*, Union Carbide Metals Co.

Static and Fatigue Strength of Metals Subjected to Triaxial Stresses
By *William Lehrer* and *Harry Schwartzbart*, Armour Research Foundation

High-Temperature Fatigue in Air and Vacuum
By *G. J. Danek, Jr.*, and *M. R. Achter*, U.S. Naval Research Laboratory

Crack Propagation in Air and Vacuum
By *R. J. Sherman* and *M. R. Achter*, U.S. Naval Research Laboratory

Damping and Fatigue Properties of High-Purity Aluminum
By *L. J. Demer*, University of Arizona

A Metallographic Study of Fatigue in High-Purity Aluminum
By *L. J. Demer*, University of Arizona

2:00 P.M. Constitution Room, Morrison Hotel

Symposium on Refractory Metals—II

Deformation of Zone-Melted Tungsten Single Crystals
By *H. W. Schadler*, General Electric Co.

Mechanical Properties of Tantalum Metal Consolidated by Melting
By *M. Schussler*, Union Carbide Metals Co. and *J. S. Brunhouse*, Aerojet-General Nucleonics

Columbium-Oxygen Reactions from 450 to 1200° C.
By *T. L. Kolski* and *W. T. Hicke*, E. I. du Pont de Nemours and Co.

Reaction of Pure Tantalum With Nitrogen, Oxygen and Air
By *W. M. Albrecht, W. D. Klopp, B. G. Kochl* and *R. I. Jaffee*, Battelle Memorial Institute

2:00 P.M. Ballroom, Morrison Hotel

Kinetics of Phase Transformations—II—Research Abstracts

A Variational Principle for the Description of Complex Metallurgical Transformations
By *J. S. Kirkaldy*, McMaster University

Further Studies of Zone Formation
By *H. Herman, M. E. Fine* and *C. Chiou*, Northwestern University

Aging Characteristics of Cu-Ti Alloys
By *G. T. Murray* and *J. B. Freeman*, Materials Research Corp.

Phase Transformations in Ni-Ti-Al Alloys
By *R. F. Decker* and *J. R. Mihalisin*, International Nickel Co., Inc.

Thermal Stability of Precipitation-Hardened and Dispersion-Hardened Nickel-Base Alloys
By *D. H. Feisel* and *Alexander Cochard*, Research Laboratories, Westinghouse Electric Corp.

Transformation Kinetics of Alpha, Beta, and Gamma Plutonium
By *R. D. Nelson*, General Electric Co.

Hardening by Internal Oxidation as a Function of Velocity of the Oxidation Boundary
By *J. L. Meijering*, Philips Research Laboratories

Growth Rate of Bainite
By *G. R. Speich*, U.S. Steel Corp., and *Morris Cohen*, Massachusetts Institute of Technology

Influence of Solution Annealing Treatment Upon Transformation Kinetics in Ti-Cr Alloys
By *H. I. Aaronson*, Ford Motor Co.

Effect of Stresses on the Ordering Transformation in Au-Cu Alloy
By *G. C. Kuczynski* and *A. Freda*, University of Notre Dame

Hall Coefficient Changes During Ordering of Cu_3Au
By *A. R. Von Neida* and *R. G. Gordon*, Yale University

2:00 P.M. Hotel Hamilton

Second Session on New Instrumentation and Techniques

Use of Beta X-Ray in Nondestructive Testing
By *Warren J. McGonnagle*, Argonne National Laboratory

Portable Spectrograph
By *David C. Miller*, Philips Electronics, Inc.

Radiography With Kilocurie Cobalt-60 Sources
By *J. A. Reynolds* and *M. R. Rosumny*, Picker X-Ray Corp.

Frequency Dependent Effects in Ultrasonic Resonance Testing
By *Robert V. Harris* and *John E. Bobbin*, Branson Instruments, Inc.

Utilization of Electrical Conductivity as a Nondestructive Tool
By *Leonard M. Taussig*, Taussig Associates

Tuesday Morning
November 3, 1959

9:00 A.M. Sherman Hotel

Steel — II

Effect of Austenitizing, Tempering and Microstructure on the Properties of a Cr-Mo-V Steel
By *F. E. Werner, T. W. Eichelberger,* and *E. K. Hann,* Westinghouse Electric Corp.

Effect of Cooling Rate From Ms to Room Temperature on Magnetic Properties of 3.5% Chromium Magnet Steel
By *W. L. Hodapp,* Crucible Steel Co. Sanderson-Halcomb Works, and *E. A. Loria,* Climax Molybdenum Co. of Pa.

Tensile Properties of Copper-Bearing Low-Carbon Steel
By *G. W. Bush,* Pennsylvania State University, and *R. W. Lindsay,* Crucible Steel Co. Central Research Laboratory

Retained Austenite in Precipitation Hardening Stainless Steels
By *G. Krauss, Jr.,* and *B. L. Averbach,* Massachusetts Institute of Technology

Effect of Small Columbium Additions to Semi-killed Medium-Carbon Steels
By *C. A. Beiser,* Union Carbide Metals Co.

9:00 A.M. Sherman Hotel

Creep and Deformation

Effect of Stress on the Creep of Aluminum in the Dislocation Climb Range
By *A. Bayce, W. D. Ludemann, L. A. Shepard* and *J. E. Dorn,* Institute of Engineering Research, University of California

Deformation of the Hard-Ductile Two-Phase Alloy System WC-Co
By *C. Nishimatsu* and *J. Gurland,* Brown University

Directional Grain Structures for High-Temperature Strength
By *F. L. VerSynder* and *R. W. Guard,* General Electric Co. Research Laboratory

Activation Energies for Creep of an Alpha Solid Solution of Magnesium in Aluminum
By *N. R. Borch, L. A. Shepard* and *J. E. Dorn,* Institute of Engineering Research, University of California

9:00 A.M. Sherman Hotel

First Metals Engineering Panel Conference on Explosive Forming

Principles and Future of Explosive Forming
By *S. J. Porter,* Consultant

Adapting Explosive Forming to Production
By *John J. Kelly,* Stanford Research Institute

Dies, Explosives and Energy Transmittal
By *C. O. Williams,* Olin Mathieson Chemical Corp.

9:00 A.M. Sherman Hotel

A.S.M.-A.E.C. Symposium on the Rare Earths and Related Metals
III — Preparation of Rare Earth Metals

Metal Production From Fluorides
By *O. N. Carlson* and *F. Schmidt,* Ames Laboratory, Iowa State University

Metal Production From Chlorides, Bromides and Iodides
By *F. E. Block,* Albany (Oregon) Station, U.S. Bureau of Mines

Metallothermic Preparation of Rare Earth Metals
By *A. H. Daane,* Ames Laboratory, Iowa State University

Metallothermic Preparation of Yttrium
By *O. N. Carlson,* Ames Laboratory, Iowa State University

Electrolytic Preparation
By *E. Morrice* and *R. G. Knickerbocker,* Reno Station, U.S. Bureau of Mines

Refining and Purification of Rare Earth Metals
By *C. L. Huffine* and *J. M. Williams,* General Electric Co., Aircraft Nuclear Propulsion Dept.

Mechanical Fabrication of Rare Earth Metals
By *Karl M. Bohlander,* General Electric Co., Aircraft Nuclear Propulsion Dept.

9:00 A.M. Ballroom, Morrison Hotel

Mechanical Properties of Nonmetals — I

Mechanical Properties of Covalent Crystals
By *J. N. Hobstetter*, University of Pennsylvania

Mechanical Properties of Ionic Crystals
By *J. J. Gilman*, General Electric Co.

Mechanical Properties of Polymeric Materials
By *T. G. Fox*, Melon Institute

9:00 A.M. Constitution Room, Morrison Hotel

Symposium: Titanium Versus Steel — I

Introduction
By *W. J. Harris, Jr.*, Materials Advisory Board, National Academy of Sciences

The General Case for Titanium
By *W. W. Minkler*, Titanium Metals Corp.

The General Case for Steel
By *R. B. Gunia*, United States Steel Corp.

Titanium in Airframes
By *E. A. Simkovich*, Republic Aviation Corp.

Steel in Airframes
By *E. A. Green*, Lockheed Aircraft Co.

Titanium in Jet Engines
By *G. J. Wile*, General Electric Co.

Steel in Jet Engines
By *Ralph Patsfall*, General Electric Co.

9:00 A.M. Cotillion Room, Morrison Hotel

Recent Advances in Steelmaking — I

(Program not definitely formulated at press time)

9:00 A.M. Embassy Room, Morrison Hotel

Symposium on Refractory Metals — I

Tin Reduction of Molybdenite
By *A. D. Abraham* and *Charles Kray*, Oregon Metallurgical Corp., and *H. G. Poole*, Colorado School of Mines

Molybdenum by Direct Thermal Dissociation of MS_2
By *W. G. Scholz, D. V. Doane* and *G. A. Timmons*, Climax Molybdenum Co. of Michigan

Tantalum Metal by Selective Solution
By *R. L. Baughman* and *D. F. Taylor*, Fansteel Metallurgical Corp.

Production and Purification of High-Purity Hafnium
By *D. S. Fairgrieve* and *J. W. Fortner*, Wah Chang Corp.

9:00 A.M. Hotel Hamilton

Panel Discussion on Nondestructive Testing Correlated With Fatigue Testing

Establishing Acceptance Standards Through Rig Testing
By *F. Nixon*, Rolls-Royce Ltd. (Derby, England)

Analytical Approach to the Study of the Effect of Small Cavities on Fatigue Strength
By *R. E. Peterson*, Westinghouse Electric Corp. Research Laboratories

Panelists: *H. N. Hill* and *I. D. Eaton*, Aluminum Co. of America

Tuesday Noon

12:00 M. Grand Ballroom, Sherman Hotel

Annual Awards Luncheon

12:15 P.M. Hollywood Room, Morrison Hotel

Powder Metallurgy Special Luncheon

Tuesday Afternoon
November 3, 1959

2:00 P.M. Sherman Hotel

Second Metals Engineering Panel Conference on Explosive Forming

Applicability and Range of Applications of the Process

Panelists:

Floyd Cox, Ryan Aeronautical Co.
Joseph L. Bird, Nitroform, Inc.
Glen Rardin, Lockheed Aircraft Co.
John Rinehart, Colorado School of Mines
John Pearson, China Lake Naval Ordnance Test Station

2:00 P.M. Sherman Hotel

Physical Metallurgy

Relationship Between State of Aging and Notch-Fatigue Performance of a High-Strength Aluminum Alloy
By *G. W. Form*, Case Institute of Technology

Precipitation Process in Cu-Cr Alloys
By *R. O. Williams*, Cincinnati Milling Machine Co.

Effect of Trace Elements on the Tensile, Electrical Resistance, and Recrystallization Properties of High-Purity Nickel
By *K. M. Olsen*, Bell Telephone Laboratories

Thermal and Electrical Conductivities of Ductile Cast Iron and Several Gray Cast Irons
By *J. H. Brophy*, Massachusetts Institute of Technology, and *M. J. Sinnott*, University of Michigan

Aluminum-Copper Composites Prepared by Solid-State Bonding
By *J. M. Williams*, Aircraft Nuclear Propulsion Dept., General Electric Co., and *M. B. Bever*, Massachusetts Institute of Technology

Substructure Characteristics of Fine-Grained Metals and Alloys Disclosed by X-Ray Reflection Microscopy and Diffraction Analysis
By *S. Weissmann*, Rutgers University

2:00 P.M. Sherman Hotel

A.S.M.-A.E.C. Symposium on the Rare Earths and Related Metals
IV — Properties of the Metals and Their Alloys

Physical Properties of the Rare Earth Metals
By *A. H. Daane*, Ames Laboratory, Iowa State University

Crystallography of the Rare Earth Metals
By *K. A. Gschneidner*, Los Alamos Scientific Laboratory

Metallography of the Rare Earth Metals
By *B. Love*, Research Chemicals Co.

Phase Diagrams
By *C. E. Lundin*, Denver Research Institute

Principles of Alloying Behavior
By *J. T. Waber* and *K. A. Gschneidner*, Los Alamos Scientific Laboratory

Mechanical Properties of Rare Earth Metals
By *C. R. Simmons*, General Electric Co., Aircraft Nuclear Propulsion Dept.

2:00 P.M. Constitution Room, Morrison Hotel

Symposium: Titanium Versus Steel — II

Titanium for Pressure Bottles
By *A. Hurlich*, General Dynamics Corp.

Steel for Pressure Bottles
By *J. F. Baisch*, Boeing Airplane Co.

Titanium for Solid Fuel Motor Cases
By *H. Hanink*, Wright Aeronautical Corp.

Steel for Solid Fuel Motor Cases
By *D. K. Hanink*, General Motors Corp.

Titanium for Marine and Chemical Plant
By *G. R. Prescott*, C. F. Braun and Co.

Other Materials for Marine and Chemical Plant
By *F. W. Fink*, Battelle Memorial Institute

2:00 P.M. Ballroom, Morrison Hotel

Properties of Nonmetals — II — Research Abstracts

Dislocation Multiplication in LiF Crystals
By *W. G. Johnston* and *J. J. Gilman*, General Electric Co.

Dislocations in Indented Mg_2O Crystals
By *A. S. Keh*, United States Steel Corp.

Dislocation Arrangements in NaCl Single Crystals
By *C. L. Bauer* and *R. B. Gordon*, Yale University

Embrittlement of NaCl by Surface Compounds
By *W. Class, E. S. Machlin* and *G. T. Murray*, Materials Research Corp.

Electrical Resistivity of Boron and Some Boron-Phosphorus Alloys
By *E. S. Greiner*, Bell Telephone Laboratories

Kinetics of Sintering of NaCl in an Inert Gas
By *J. B. Moser* and *D. H. Whitmore*, Northwestern University

Effect of Grain Size on Deformation of Polycrystalline AgCl
By *R. D. Carnahan, T. L. Johnston, R. J. Stokes* and *C. H. Li*, Mineapolis-Honeywell Regulator Co.

Diffusion of Lead in Single Crystals of Lead Selenide
By *Martin Seltzer and J. B. Wagner, Jr.*, Yale University

Diffusion of Lead in Single Crystals of Lead Sulphide
By *George Simkovich* and *J. B. Wagner, Jr.*, Yale University

Stress-Strain Characteristics of Lithium Fluoride Single Crystals
By *W. L. Phillips, Jr.*, E. I. du Pont de Nemours and Co., Inc.

2:00 P.M. Cotillion Room, Morrison Hotel

Recent Advances in Steelmaking — II
(Program not formulated at press time)

2:00 P.M. Embassy Room, Morrison Hotel

Refining of Pure Metals

High-Purity Single Crystals of Indium Antimonide
By *S. E. Miller* and *W. P. Allred*, Battelle Memorial Institute

Zone Refining of Reactor Metals
By *G. E. Spangler, M. Herman, J. L. Rutherford* and *R. L. Smith*, Franklin Institute

Floating-Zone Refining of Heavy Metals Using Electron Beam
By *W. P. Allred* and *R. C. Himes*, Battelle Memorial Institute

2:00 P.M. Hotel Hamilton

First Session on Component Reliability

Automatic Inspection of Jet Rotors
By *H. E. Van Valkenburg*, Sperry Products, Inc.

Radiographic Inspection of Sealed Electronic Components
By *Leslie T. Hahn*, Convair

Nondestructive Testing of Large Solid Propellant, Case Bonded Rocket Motors
By *J. H. Cusick*, U. S. Naval Ammunition Depot, Concord, Calif.

Glueline Thickness Measurements by Eddy Current Inspection
By *Leo L. Soffa*, Northrup Corp.

An Evaluation of Coating Thickness Testing Methods
By *Clifford L. Gough*, Perfect Circle Corp.

Propellant Inspection by High Voltage Radiation
By *D. Polansky, E. L. Criscuolo*, and *J. A. Holloway*, Naval Ordnance Laboratory

Tuesday Evening

6:30 P.M. Ballroom, Morrison Hotel

A.I.M.E. Cocktail Party and Dinner

Wednesday Morning
November 4, 1959

9:00 A.M. Sherman Hotel

A.S.M. Annual Meeting
Campbell Memorial Lecture

The Role of Hydrogen and Other Interstitials on the Mechanical Behavior of Metals
By *A. R. Troiano*, Case Institute of Technology

9:00 A.M. Ballroom, Morrison Hotel

Symposium on Irradiation of Fuel and Fuel Elements — I

Nature of Fission Damage
By *J. A. Brinkman*, Atomics International Division of North American Aviation, Inc.

Variables Affecting the In-Pile Behavior of Fuel Materials
By *H. J. Levinstein* and *R. H. Fillnow*, Bettis Atomic Power Division, Westinghouse Electric Corp.

Swelling and Fission Gas Agglomeration in Metal Fuels
By *A. T. Churchman*, Central Electricity Generating Board (London, England)

Nature of Inert Gas Agglomeration and Swelling in Metals
By *R. S. Barnes*, Atomic Energy Research Establishment (Harwell, England)

Operational Performance of Bonded and Unbonded Uranium Fuel Rods
By *T. T. Claudson*, *G. T. Geering*, *J. W. Goffard* and *J. E. Minor*, Hanford Atomics Products Operation, General Electric Co.

Irradiation Behavior of U-FS and U-Pu-FS Fast Reactor Fuels
By *J. A. Horak* and *J. H. Kittel*, Argonne National Laboratory

Irradiation Behavior of U-Cb and U-Cb-Zr Alloys
By *R. H. Fillnow*, *F. E. Card*, *D. E. Thomas*, *S. B. McRickard* and *H. J. Levinstein*, Bettis Atomic Power Division, Westinghouse Electric Corp.

Crystallographic Study of Radiation-Induced Recovery in Cold Worked Uranium
By *D. Tardivon*

9:00 A.M. Constitution Room, Morrison Hotel

Surfaces and Quantitative Metallography

Thermal Etching of Silicon Iron
By *D. S. Hutton* and *W. C. Leslie*, U. S. Steel Corp.

Theory of Lateral Facet Growth by Surface Diffusion
By *W. W. Mullins*, Westinghouse Electric Corp.

Relative Energies of Tilt-Type Sub-Boundaries in Aluminum
By *K. T. Aust*, General Electric Co.

Influence of Surface Intersections on Crystal Growth From the Melt
By *W. A. Tiller* and *G. F. Bolling*, Westinghouse Electric Corp.

Quantitative Metallography for Volume-Fraction Analysis
By *J. E. Hilliard* and *J. W. Cahn*, General Electric Co.

9:00 A.M. Cotillion Room, Morrison Hotel

Research Abstracts on Precipitation and Dispersion Hardening

Evidence of an Ordered Metastable Phase in Au-Ni Alloys
By *J. R. Cost* and *C. A. Wert*, University of Illinois

Electrical Resistivity of Cu-Fe Alloys After Plastic Deformation
By *Alvin Boltax*, Nuclear Metals Inc.

Criteria for Yielding of Dispersion-Strengthened Alloys
By *G. S. Ansell* and *F. V. Lenel*, Rensselaer Polytechnic Institute

Dispersed Particle Hardening of Al-Cu Single Crystals
By *D. Dew-Hughes*, International Business Machines Corp., and *W. D. Robertson*, Yale University

Mechanism of Hardening in Aged Al-Cu Alloys
By *D. Dew-Hughes*, International Business Machines Corp., and *W. R. Robertson*, Yale University

Strengthening by Precipitates in Al-Cu Alloys
By *J. G. Byrne*, *A. Kelly* and *M. E. Fine*, Northwestern University

9:00 A.M. Embassy Room, Morrison Hotel

Titanium — III — Research Abstracts

Effect of Hydrogen and Other Variables on Thermal Stability of Titanium High in Aluminum
By *S. R. Seagle* and *Stanley Abkowitz*, Mallory-Sharon Metals Co.

Stabilization of Certain Ti_2Ni-Type Phases by Oxygen
By *M. V. Nevitt*, Argonne National Laboratory

The Ti-TiO-ZrO_2-Zr System
By *Michael Hoch*, *R. L. Dean* and *S. M. Wolosin*, University of Cincinnati

Effect of Rare Earth Additions on the Transition Temperature and Lattice Parameter of Alpha Titanium
By *C. G. Kirkpatrick*, *Bernard Love* and *Virgil Novy*, North American Aviation, Inc.

A Mold Material for Titanium Castings
By *A. R. C. Westwood*, RIAS

Vacuum Arc Melting and Casting of Titanium
By *B. W. Huber* and *E. J. Chapin*, U. S. Naval Research Laboratory

9:00 A.M. Hotel Hamilton

Second Session on Component Reliability

Automatic Cladding Thickness and Bonding Tester for Reactor Fuel Elements
By *David O. Hunter*, Hanford Atomic Products Operation

Inductive Thermometry
By *Hugo L. Libby*, Hanford Atomic Products Operation

Studies in Broadband Eddy Current Testing
By *Hugo L. Libby*, Hanford Atomic Products Operation

A Through Transmission System Using Pulsed Eddy Currents
By *C. J. Renken*, Argonne National Laboratory

Automatic Particle Size Determination for Microradiographs
By *William Distler* and *Valmore Reshenk*, Lawrence Radiation Laboratory, and *Gordon Miller*, Sandia Corp.

Wednesday Noon

University Alumni Luncheons

The 1959 Luncheon Hotel Hamilton

Address on "Nondestructive Testing in Medicine"
By *Charles O. Bechtol, M.D.*

Wednesday Afternoon
November 4, 1959

2:00 P.M. Sherman Hotel

Mechanical Working

Effect of Rolling Variables on the Hot Rolling of Titanium and Titanium Alloys
By *F. R. Larson* and *J. Nunes*, Watertown Arsenal

Effect of Initial Increments of Hot Working on the Mechanical Properties of Certain Ferrous Materials
By *H. J. Wagner*, Battelle Memorial Institute, and *J. W. Spretnak*, Ohio State University

The Thermo-Mechanical Method for Relieving Residual Quenching Stresses in Aluminum Alloys
By *H. N. Hill*, *R. S. Barker* and *L. A. Willey*, Alcoa Research Laboratories

Calculation of Rolling Forces Using the Orowan Theory
By *J. E. Hockett*, Los Alamos Scientific Laboratory

Effect of Selenium on the Machinability and Tensile Properties of 5% Cr Steel
By *F. W. Boulger*, Battelle Memorial Institute

2:00 P.M. Sherman Hotel

Metals Engineering Panel Conference on Refractory Metals

Beryllium
By *N. W. Bass*, Brush Beryllium Co.

Vanadium
By *T. W. Merrill*, Vanadium Corp of America

Columbium
By *Ralph H. Hiltz*, Tapco Group, Thompson Ramo Wooldridge Inc.

2:00 P.M. Sherman Hotel

Metal Powder Industries Federation in Cooperation With Powder Metallurgy Parts Manufacturers Assoc.

Powder Metallurgy Clinic—Advantages, Limitations, Applications
Case Histories of Parts
Principles of Powder Metallurgy (Movie)
Panel Discussion

2:00 P.M. Constitution Room, Morrison Hotel

Research Abstracts on Plasticity and Strength of Single Phases

Effect of Quenching on Mechanical Properties of Molybdenum
By *W. Liebmann* and *Robert Maddin*, University of Pennsylvania

Structure, Formation and Properties of Chromium Filaments
By *S. T. Wlodek*, *W. W. Webb* and *W. D. Forgeng*, Union Carbide Metals Co.

Tensile Deformation of Aluminum Single Crystals at Low Temperatures
By *W. F. Hosford, Jr.*, *R. L. Fleischer* and *W. A. Backofen*, Massachusetts Institute of Technology

Mechanism of Deformation Leading to Tensile Fracture of Aluminum and Copper
By *W. D. Sylwestrowicz*, Bell Telephone Laboratories

The Hedge Mechanism for Work Hardening
By *U. F. Kocks*, Harvard University

Strain Aging in Ag-Al Alloys
By *A. A. Hendricksen* and *M. E. Fine*, Northwestern University

Yield Point Phenomena in Commercial Copper Alloys and One Nickel-Base Alloy
By *V. A. Phillips*, General Electric Co., and *R. B. Jones*, Sheffield University, (England)

Solution Hardening by Interaction of Impurity Gradients and Dislocations
By *R. L. Fleischer*, Massachusetts Institute of Technology

Deformation Characteristics of Mo-Re Alloy
By *Alan Lawley* and *Robert Maddin*, University of Pennsylvania

2:00 P.M. Ballroom, Morrison Hotel

Symposium on Effects of Irradiation on Fuel and Fuel Elements — II

Irradiation Behavior of UO_2 Fuel Elements
By *J. A. L. Robertson, A. S. Bain, G. M. Allison* and *W. H. Stevens*, Atomic Energy of Canada Ltd.

Swelling of UO_2 at High Burnup
By *W. K. Barney*, Knolls Atomic Power Laboratory, General Electric Co.

Irradiation Testing of Plutonium-Uranium Oxide Nuclear Fuel
By *J. L. Bates* and *W. E. Roake*, Hanford Atomic Products Operation, General Electric Co.

Effect of Radiation on Massive Uranium Carbide
By *H. Pearlman*, Atomics International Division of North American Aviation, Inc.

Irradiation Behavior of ThO_2-UO_2 Fuels
By *L. A. Neimark* and *J. H. Kittel*, Argonne National Laboratory

Release of Fission Products From Fueled Graphite
By *W. C. Riley, D. N. Sunderman* and *B. W. Dunnington*, Battelle Memorial Institute

2:00 P.M. Cotillion Room, Morrison Hotel

Refractory Metals — II — Research Abstracts

Fatigue and Tensile Properties of Columbium at Elevated Temperatures
By *J. F. Enrietto, G. M. Sinclair* and *C. A. Wert*, University of Illinois

Alloy Strengthening of Columbium
By *W. F. Sheely*, Union Carbide Metals Co.

Strengths of Some Columbium-Base Alloys
By *W. H. Chang*, General Electric Co.

Effect of Prestrain and Polygonization on Creep of Molybdenum
By *A. Iannucci, J. Intrater* and *Sheldon Weinig*, Materials Research Corp.

Refractory Metal Thermocouples
By *J. C. Lachman*, Aircraft Nuclear Propulsion Dept., General Electric Co.

Elevated Temperature Strength of Tungsten
By *G. H. Keith* and *E. F. Vandergrift*, Westinghouse Electric Corp.

Physical and Mechanical State of Compacted Tungsten Powders as a Function of Pressing Rate, Particle Size Distribution and Impurities
By *H. G. Sell*, Westinghouse Electric Corp.

Mechanical Properties of Tungsten Wire
By *A. J. Opinsky*, Sylvania Electric Products, Inc.

Mechanical Properties of Tungsten
By *E. L. Harmon*, Union Carbide Metals Co.

Properties of Slip-Cast Tungsten
By *G. Reinhardt* and *F. R. Charvat*, Union Carbide Metals Co.

Determination of Latent Heats of Impurities Which Undergo Phase Transformations When Tungsten Powder Compacts are Sintered
By *H. G. Sell*, Westinghouse Electric Corp.

2:00 P.M. Embassy Room, Morrison Hotel

Research Abstracts on Oxidation and Reduction

Thermodynamic Properties of Titanium-Oxygen, Zirconium-Oxygen, and Hafnium-Oxygen Alloys
By *K. L. Komarek*, New York University

Oxidation of Iron in CO-CO_2 Atmospheres
By *W. M. Smeltzer*, McMaster University

Mechanism of Oxidation of Iron in CO-CO_2 Mixtures
By *Frederick Pettit, Robert Yinger* and *J. B. Wagner, Jr.*, Yale University

Oxidation of Ni-Rich Cu-Ni Alloys
By *J. A. Sartell* and *C. H. Li*, Minneapolis-Honeywell Regulator Co.

Oxidation Characteristics of Columbium Alloys Containing W, Mo, Ti, and Al
By *W. H. Chang*, General Electric Co.

Dispersed Phase Alloys of Aluminum and of Silver
By *H. R. Peiffer*, RIAS

Equilibrium Study of Magnesium Reduction of Uranium Dioxide in Bismuth Matrix
By *R. E. Balzhiser, E. E Hucke* and *D. V. Ragone*, University of Michigan

Effect of Arsenic on the Reduction of Tungstic Oxide
By *J. M. Laferty, Jr.*, Sylvania Electric Products, Inc.

Effect of Impurities on the Reduction of Tungstic Oxide
By *P. C. Fisher, Jr.* and *J. M. Laferty, Jr.*, Sylvania Electric Products, Inc.

2:15 P.M. Hotel Hamilton

Annual Meeting and Honor Session
The Lester Lecture

The Nondestructive Testing Engineer—Today's Career Opportunity
By *Carl E. Betz*, Magnaflux Corp.

Presentation of the DeForest and the Coolidge Awards

Annual Business Meeting of the Society

Thursday Morning November 5, 1959

9:00 A.M. Sherman Hotel

Nuclear Metals

High-Strength Zirconium Alloys
By *R. K. Wagner* and *H. E. Kline* Atomics International

Effect of Uranium Hydride Distribution and Recrystallization on the Tensile Properties of Uranium
By *H. R. Gardner* and *J. W. Riches*, General Electric Co.

Textures in Extruded Uranium
By *R. B. Russell*, Nuclear Metals, Inc.

Transformation Kinetics and Mechanical Properties of Uranium with 0.5% Cb and 0.5% Mo
By *E. G. Zukas*, Los Alamos Scientific Laboratory

Metallographic Study of Stringers in Zircaloy-2 Melted in Inert Atmosphere
By *J. D. Grozier, L. S. Rubenstein* and *J. G. Goodwin*, Westinghouse Electric Corp.

9:00 A.M. Sherman Hotel

Austenitic Alloys

Some Metallurgical Factors Affecting Stress-Corrosion Cracking of Austenitic Stainless Steels
By *H. H. Uhlig*, Massachusetts Institute of Technology, and *R. A. White*, Standard Oil Co. of Calif.

Tensile and Yield Strength of Cr-Mn-N Steels at Low Temperatures
By *J. C. Shyne, F. W. Schaller* and *V. F. Zackay*, Ford Motor Co. Scientific Laboratory

Effect of Interstitial Carbon Plus Nitrogen and Precipitation Reactions on the Properties of Austenitic Cr-Mn-C-N Steels
By *C. M. Hsiao*, Peking Institute of Iron and Steel (Peking, China), and *E. J Dulis*, Crucible Steel Co. of America

The Role of Boron in Cast Austenitic Alloys
By *R. W. Kraft, Jr.*, United Aircraft Corp., and *R. A. Flinn* University of Michigan

Structure and Properties of Austenitic Alloys Containing Aluminum and Silicon
By *D. J. Schmatz*, Ford Motor Co. Scientific Laboratory

Ferromagnetic Cobalt-Base High-Temperature Alloy
By *A. Cochardt*, Westinghouse Electric Corp. Research Laboratories

9:00 A.M. Grand Ballroom, Sherman Hotel

Today's Uses of Ultrasonics

Ultrasonic Cleaning
By *H. F. Osterman*, Branson Ultrasonic Corp., and *Stanley R. Rich*, General Ultrasonics Co.

Ultrasonic Processing
By *Paul M. Platzman*, Narda Ultrasonics Corp., and *Thomas J. Bulat*, Pioneer-Central Div., Bendix Aviation Corp.

Ultrasonic Drilling, Machining and Grinding
By *Harvey B. Foulkes, Jr.*, Cavitron Equipment Corp., and *Paul A. Sorensen*, Raytheon Manufacturing Co.

Ultrasonic Welding, Soldering and Brazing
By *William C. Potthoff*, Aeroprojects, Inc.

9:00 A.M. Ballroom, Morrison Hotel

Melting and Casting of Nonferrous Metals — I — Current Practices

Melting and Casting of Zinc at Trail, B. C.
By *J. M. Buchanan*, Consolidated Mining and Smelting Co. of Canada, Ltd.

Current Practices in the Melting and Casting of Copper Alloys
By *P. H. Kirby*, American Brass Co.

Gas and Its Control in the Casting of Aluminum
By *Donald La Velle*, American Smelting and Refining Co.

Factors Affecting the Structure of Continuously Cast Slabs of Aluminum
By *Dieter Altenpohl*, Aluminum Foils, Inc

Melting and Casting Nickel Alloys
By *C. G. Bieber*, International Nickel Co.

9:00 A.M. Constitution Room, Morrison Hotel

Recovery, Grain Growth, and Textures — I — Research Abstracts

Recovery of the Extra-Resistivity of Cold Worked Cadmium From 100 to 273° K.
By *H. R. Peiffer* and *F. R. Stevenson*, RIAS

Effect of Cold Rolling Procedure on Recrystallization of Iron
By *J. T. Michalak*, U.S. Steel Corp., and *W. R. Hibbard, Jr.*, General Electric Co.

Preferred Orientation Resulting From Simple Shear
By *R. O. Williams*, Cincinnati Milling Machine Co.

Kinetics of the Energy Release From Deformed Metals and Alloys
By *R. O. Williams*, Cincinnati Milling Machine Co.

Polygonization of 31% Alpha-Brass
By *V. Y. Doo*, International Business Machines Corp.

Subgrain Growth and Softening in Rolled Aluminum Crystals
By *B. G. Ricketts*, University of Illinois, *A. Kelly*, Cambridge University, and *P. A. Beck*, University of Illinois

Recrystallization of Cold Drawn, Sintered Aluminum Powder
By *E. J. Westerman*, General Electric Co., and *F. V. Lenel*, Rensselaer Polytechnic Institute

Effect of Impurities on the Recrystallization of Tantalum
By *M. A. Cocca*, General Electric Co.

Migration of Grain Boundaries in Zone-Refined Lead Containing Very Dilute Additions of Ag and Au
By *K. T. Aust* and *J. W. Rutter*, General Electric Co.

Swelling of Irradiated Alloy Fuels During Post-Irradiation Annealing
By *W. V. Johnston*, General Electric Co.

9:00 A.M. Cotillion Room, Morrison Hotel

Research Abstracts on Imperfections

Dislocation Etch Pits and Plastic Deformation in Copper Single Crystals
By *J. D. Livingston*, General Electric Co.

Dislocation Networks in Zinc Crystals
By *V. V. Damiano*, Franklin Institute

Mobility of Edge Dislocations in Silicon-Iron Crystals
By *D. F. Stein* and *J. R. Low, Jr.*, General Electric Co.

Individual Dislocations in Alpha Brass
By *J. D. Meakin* and *H. G. F. Wilsdorf*, Franklin Institute

Observation of Dislocations in Aluminum by X-Ray Extinction Contrast
By *J. M. Lommel*, General Electric Co.

Dislocations and Sub-Boundaries in Metal Crystals Grown From the Melt
By *C. Elbaum*, Brown University

X-Ray Measurement of Stacking Faults in Deformed Cu-Si Wires
By *D. H. Felter* and *H. M. Otte*, RIAS

Dislocations Formed by Vacancy Condensation
By *G. Schoeck* and *W. A. Tiller*, Westinghouse Electric Corp.

Contribution of Dislocation Line Tension and the Density of the Solute Atmosphere to the Yield Point in Strain-Aged Ingot Iron
By *T. Mura* and *J. O. Brittain*, Northwestern University

Effect of Orientation and Pre-Strain on the Delay Time of Aluminum Single Crystals
By *I. R. Kramer*, RIAS

9:00 A.M. Embassy Room, Morrison Hotel

Powder Metallurgy — I

Molecular Processes at the Gas-Metal Interface
By *Gert Ehrlich*, General Electric Co.

Effects of Oxide Films on the Sintering Behavior of Metal Powders
By *H. H. Hausner*, Consultant

Equilibrium Phenomena Between Gases and Solid Surfaces in Sintered Metals
By *Michael Eudier*, La Metallurgie Francaise des Poudres Metafram (France)

9:00 A.M. LaSalle Hotel

Vitis to Institute for the Study of Metals
(Open to Metals Division Members Only)

Informal Discussions of Research in

Solid State Physics	By	*Earl Long*
Theoretical Metallurgy		*Cyril Stanley Smith*
Temperatures Nearing 0° K.		*Andrew Lawson*
Effects of Very High Pressures		*Charles Barrett*
		Robert Gomer

9:00 A.M. Hotel Hamilton

Third Session on Component Reliability

Radiographic Technique at 250 Kvp.
By *J. A. Holloway, D. Polansky* and *E. L. Criscuolo,* U.S. Naval Ordnance Laboratory

Nondestructive Testing Techniques for Components of Critical Antifriction Bearings
By *E. W. Garrison,* Marlin Rockwell Corp.

Recent Advances in Ultrasonic Research and Development
By *Herbert E. Elion,* Elion Instruments, Inc.

Flaw Detection and Bond Testing With Ultrasonic Recorders
By *R. E. Kleint* and *H. Mitchell,* Ultrasonic Testing and Research Laboratory

Ultrasonic Inspection — Its Present and Future Status
By *John W. Orner,* Watertown Arsenal

Thursday Afternoon November 5, 1959

1:00 P.M. Argonne National Laboratory

(Open to Metals Division Members Only)

Lunch in West Area Cafeteria
Tour of Physics Library
Orientation on Technical Information Division
Tour of Chemistry Library
Tour of "Hot" Laboratory
Tour of "CP-5 Research Reactor"

2:00 P.M. Sherman Hotel

Refractory Metals

Properties of Refractory Alloys Containing Rhenium
By *C. T. Sims,* Knolls Atomic Power Laboratory, and *R. I. Jaffee,* Battelle Memorial Institute

Flow, Fracture and Twinning of Commercially Pure Vanadium
By *W. R. Clough,* Connecticut Operations (Canel) of Pratt and Whitney Aircraft, and *A. S. Pavlovic,* Union Carbide Metals Co.

An Exploration of High-Boron Alloys
By *A. U. Seybolt,* General Electric Co. Research Laboratory

The Columbium-Oxygen System
By *R. P. Elliott,* Armour Research Foundation

High-Temperature Oxidation of W-Cb Alloys
By *J. W. Semmel,* General Electric Co. Flight Propulsion Laboratory

2:00 P.M. Sherman Hotel

Heat Treating to Rigid Specifications

Carbon Control During Heat Treatment
By *Frank Hobbs,* Ispenlab of Canada Ltd.

How to Obtain Specified Requirements Through Heat Treating
By *L. J. Haga,* State Heat Treat, Inc.

Panel on Heat Treatment of Gears
N. O. Kates: Furnace and induction
J. Howat: Flame
H. C. Knerr: Nitriding
M. Soviak: Salt Bath

2:00 P.M. Ballroom, Morrison Hotel

Nonferrous Melting and Casting — II — Research Summaries

Vacuum Induction Melting of Mg-Li Alloys
By *R. J. Jackson, T. G. Byrer* and *P. D. Frost*, Battelle Memorial Institute

Effect of Production Variables on the Quality of Light Alloy Castings
By *J. W. Meier*, Department of Mines and Technical Surveys (Ottawa, Canada)

Some Factors Influencing Grain Refinement in Nonferrous Alloys
By *Walter Showak*, Ford Motor Co.

A Cold-Mold Induction Furnace for Melting Reactive Metals Without Contamination
By *G. H. Schippereit* and *A. F. Leatherman*, Battelle Memorial Institute, and *D. Evers*, Mallory-Sharon Metals Corp.

2:00 P.M. Constitution Room, Morrison Hotel

Recovery, Grain Growth, and Textures — II — Research Abstracts

Evolution of Deformation and Recrystallization Textures in Cu-Ge and Cu-Sn Alloys
By *Y. C. Liu* and *R. H. Richman*, Ford Motor Co.

Effect of Grain Growth on the Cube Texture in an Al-Mn Alloy
By *T. J. Koppenaal*, Northwestern University, *M. N. Parthasarathi* and *P. A. Beck*, University of Illinois

A Texture Problem Involving Orientation Density
By *C. G. Dunn* and *J. L. Walter*, General Electric Co.

Secondary Recrystallization in Cube-Textured 50% Ni, 50% Fe Alloy Tapes
By *N. I. Ananthanarayanan, R. H. Buckwalter* and *R. G. Aspden*, Westinghouse Electric Corp.

Texture of Silicon Iron
By *P. K. Koh*, Allegheny Ludlum Steel Corp., and *C. G. Dunn*, General Electric Co.

Influence of Constraints During Rolling on the Textures of 3% Si Iron Crystals Initially (001) [100]
By *R. G. Aspden*, Westinghouse Electric Corp.

Cube Growth in Silicon Iron
By *G. W. Wiener*, Westinghouse Electric Corp.

Initial Growth of Cube-Oriented Secondary Recrystallization Nuclei in High-Purity Silicon-Iron
By *J. L. Walter* and *C. G. Dunn*, General Electric Co.

Nature of the Matrix for Secondary Recrystallization to the Cube Texture in High-Purity Silicon-Iron
By *C. G. Dunn* and *J. L. Walter*, General Electric Co.

2:00 P.M. Cotillion Room, Morrison Hotel

Heat Treatment and Properties of Steels

Anomalous Kinetics of the Bainitic Transformations Just Above the Ms Temperature
By *M. F. Smith*, Nuclear Metals, Inc., *G. R. Speich*, U.S. Steel Corp., and *Morris Cohen*, Massachusetts Institute of Technology

Effect of Pressure on the Martensitic Transformations in the Iron-Nickel System
By *L. Kaufman, S. A. Kulin* and *H. Udin*, Manufacturing Laboratories, Inc.

Effect of Heat Treatment in the Ferrite-Austenite Region of Notch Toughness of Low-Carbon Steels
By *W. C. Leslie, R. L. Rickett* and *W. D. Lafferty*, U.S. Steel Corp.

Preferred Orientation in Warm-Worked and Heat Treated 4340 Steel
By *E. P. Kula* and *S. L. Lopata*, Watertown Arsenal

Effect of Sulphur on the Notch Toughness of Heat Treated Steels
By *J. M. Hodge, R. H. Frazier* and *F. W. Boulger*, Battelle Memorial Institute

Magnetism in 0.30 C, 18 Cr, 8 Ni, 3 Si Valve Steel Alloys
By *S. M. Purdy*, Carpenter Steel Co.

Effect of Tensile and Creep Prestrain on a Precipitation Hardening, High-Temperature Alloy
By *J. T. Brown*, Westinghouse Electric Corp.

Measurement of Chi and Sigma Phases in Stainless Steel With the Electron Probe Microanalyzer
By *L. S. Birks* and *J. Siomkajlo*, U.S. Naval Research Laboratory, and *P. K. Koh*, Allegheny Ludlum Steel Corp.

Recrystallization of Austenite
By *R. A. Grange*, U.S. Steel Corp.

2:00 P.M. Embassy Room, Morrison Hotel

Powder Metallurgy — II

Infiltration of Alumina With Silver
By *J. W. Proske* and *A. J. Shaler*, Pennsylvania State University

Coulometric Reduction; a Tool for Studying Surface Films
By *V. J. Albano*, Bell Telephone Laboratories

Effects of Surface Parameters on Dimensional Changes in Iron-Copper Sinterings
By *Morse Hill* and *H. P. Munger*, Republic Steel Corp.

2:00 P.M. Hotel Hamilton

Panel Discussion
Problems Facing the Aircraft Industry in Inspection of Brazed Honeycomb Structures

Panel Members: *William C. Hitt*, Douglas Aircraft Co., Inc.
H. Harris, North American Aviation Corp.
Robert Booth, Boeing Airplane Co.
John D. Fenton, Convair
William Mays, North American Aviation Corp.
G. E. Molzahn, Lockheed Aircraft Corp.

Thursday Evening

6:00 P.M. La Salle Hotel

Banquet With Illinois Chapter, S.L.A.

7:30 P.M. Sherman Hotel

A.S.M. Annual Banquet

Friday Morning November 6, 1959

SNT

9:00 A.M. Hotel Hamilton

First Session, Educational Clinic

Scope of Present Nondestructive Testing Field
By *D. W. Ballard,* Sandia Corp.

Radiography, Including Isotope Radiography
By *W. D. Kiehle,* Eastman Kodak Co.

Darkroom Techniques
By *S. S. Stacey,* Ansco Corp.

Fluoroscopy
By *W. Hampe,* Westinghouse Electric Corp.

Magnetic Particle Inspection
By *W. E. Thomas,* Magnaflux Corp.

SLA

9:30 A.M. LaSalle Hotel

Session on Steelmaking and Product Packaging

Continuous Converting of Cupola Iron Into Steel by Oxygen Blowing
By *W. F. Hinkle,* Acme Steel Co.

Latest Developments in Packaging Design
By *J. H. Myers,* Acme Steel Co.

Strapping Machines in the Packaging Field
By *H. Connell,* Acme Steel Co.

Friday Afternoon November 6, 1959

SLA

12:45 P.M. LaSalle Hotel

Inspection Trip to Acme Steel Co.

(Open to Metals Division Members Only)
By bus to Riverdale to tour the recently installed continuous cupola, oxygen converter process of steelmaking

SNT

1:30 P.M. Hotel Hamilton

Second Session, Educational Clinic

Penetrant Inspection
By *H. Migel,* Magnaflux Corp.

Eddy Current Test Methods
By *H. L. Libby,* Hanford Atomic Products

Ultrasonics; Theory and Instrumentation
By *H. E. VanValkenburg,* Sperry Products

Ultrasonics; Applications and Interpretations
By *W. C. Hitt,* Douglas Aircraft Co.

Writing in Modern Technology
By *R. Nelsen,* General Electric Co.

Friday Evening

6:00 P.M. International Ampitheater

41st Annual Metal Exposition Closes

Exhibitor Listing

A

Aaron Machinery Co., Inc. 1246

Adolph Plating, Inc. 1298
Metal parts coated and finished with various metals from cadmium through silver.

Aerobraze Corp. 1509
Brazing and heat treating of stainless steel assemblies (service).

Aero-Test Equipment Co., Inc. 1659
See Perfecto-Peen Division.

Aircraft & Missiles Mfg. 1410
Business publication.

Ajax Electric Co. 1526
Salt bath furnaces.

Ajax Engineering Division 1506
See Ajax Magnethermic Corp.

Ajax Magnethermic Corp. 1506
Induction furnaces and heat treating equipment using 60-cycle and high-frequency current.

Aktiebolaget Curto 1542
See Curto Co.

Allen Machine Tool Corp., Steve 1562

Allen Mfg. Co., W. D. 1855
Multiple drilling and tapping machines; quick-change tool holders; boring bars; punches and shears.

Allied Research Products, Inc. 1212
Electroplating equipment and processes.

Allison-Campbell Division, American Chain & Cable Co., Inc. 1236
Abrasive cutting wheels; wet and dry abrasive cutting machines; heavy duty dry abrasive cutting machines; grinding coolant.

Alloy Engineering & Casting Co. 841
Heat resistant and corrosion resistant alloy castings.

Alloy Products Corp. 1533
Fabricated and stamped stainless steel shapes, forms and fittings.

American Brake Shoe Co. Electro-Alloys Division 727
Heat resistant alloy castings.

American Cast Iron Pipe Co. 1230
Centrifugally spun steel tubing and castings.

American Chain & Cable Co., Inc. 953 and 1236
See Allison-Campbell Div. and Wilson Mechanical Instrument Div.

American Cystoscope Makers, Inc. 201
Borescopes, miniature lamps and optical flats.

American Gas Association 754
Industrial gas burners, gas heated ovens and furnaces.

American Gas Furnace Co. 728
Controlled atmosphere, shaker hearth furnaces and continuous rotary retort furnaces, with automatic feeders.

American Machine & Foundry Co. DeWalt Division 1846
Radial arm machinery for cutting wood, metals and plastics.

American Machine & Metals, Inc. 641
See Riehle Testing Machine Division.

American Machinist 1321
McGraw-Hill publication.

American Optical Co., Instrument Division 309
Metallographic and other optical scientific instruments used in the metal industry.

American Pullmax Co., Inc. 1705
Universal shearing and forming machines.

American Sealants Co. 1751
Liquid lock for metal parts known as Locktite Sealant.

American Society for Metals 810
Metal Progress and *Metals Review* (monthly magazines); Books for the metals industry; Metallurgical Engineering Institute (home study courses). Mechanized literature searching project.

American Steel Foundries 855
Shell molded castings.

Amersil Quartz Division 1430
See Engelhard Industries, Inc.

Amplex Division, Chrysler Corp. 1745
"Oilite" self-lubricating bearings, precision parts made by powder metallurgy, and metal filters.

Anderson Brothers Mfg. Co. 1461
Straightening presses, power and hand scrapers, balancing ways.

Anocut Engineering Co. 1416
Electrolytic machining equipment.

Arcair Co. 1798
Automatic or manual process for gouging, cutting and metal removal; welding accessories.

Arcweld Mfg. Co. 735
High-temperature testing and creep testing equipment; thermocouple calibrators; gradient furnaces; vacuum retorts.

Armstrong Brothers Tool Co. 1624
Hand tools, tool holders, carbide insert tools, wrenches, cutters, clamps.

Ashland Oil & Refining Co. 1460
See National Refining Co.

Atkins Saw Division Borg-Warner Corp. 1861

Atlas Press Co. 1550
Machine tools (lathes, drill presses, milling machines).

Atom Wheel Tool 1740
"Atom Wheel Tool"—a new concept in metal fabrication.

Austin Tool Co., Inc. 1264
See Frank Loy & Assoc.

Automotive Industries 1410
Business publication.

B

Babcock & Wilcox Co., Tubular Products Div. 528
Seamless tubing, tubular products, extrusions, fittings for weldments.

Baj Tool Co. 1511
Hand, adjustable and high speed keys, key-way broaches.

Balteau Electric Corp. 120
Industrial X-ray Equipment and accessories.

Banner Welder, Inc. 1415
Resistance welding machines.

Barber-Colman Co. 1455
See Wheelco Instruments Div.

Barer Engineering & Machinery Co., Ltd. 502
Machine tools: lathes, drill presses, shapers and grinders.

Barry Controls, Inc. 1708
Leveling mounts for industrial machinery; metalworking tools.

Battelle Memorial Institute 819
See Cobalt Information Center.

Bausch & Lomb Optical Co. 219
Optical gages, research metallographs, metallurgical, toolmakers' and electroplaters' microscopes, bench comparators, cameras, color analyzers, stereomicroscopes.

Beryllium Corp. 1636
Beryllium chemicals, metal and alloys.

Binks Mfg. Co. 1541
Paint spraying equipment for manual and automatic operation; air compressors; air operated fluid handling pumps; electro - mechanical memory timers.

Blakeslee & Co., G. S. 1641
Machines for degreasing and cleaning metal parts; paint spraying units; ultrasonic equipment for cleaning and other purposes.

Blue M Electric Co. 1442
Temperature control equipment for ovens, furnaces, liquid baths and humidity cabinets.

Borg-Warner Corp. 1861
See Atkins Saw Division.

Bowman Products Co. 1655
See E. I. du Pont de Nemours & Co., Inc., Explosives Department.

Bradley Washfountain Co. 1663
Wash fountains and group showers.

Branson Instruments, Inc. 1645
See Branson Ultrasonic Corp.

Branson Ultrasonic Corp. 1645
Ultrasonic cleaning and testing equipment, generators, transducers, dip tanks.

Brinkmann Instruments, Inc. 315
Laboratory instruments, dilatometers, balances, thermostats, microscopes.

British Industries Corp. 1463
See Shaw Process Development Corp.

Brown & Sharpe Mfg. Co. 1357
Micrometer and vernier calipers, snap gages, height gages, dial indicators, surface and sine plates, magnetic chucks, precision-ground flats and tool-steel bars.

Charles Bruning Co., Inc. 919
Copying machines and drafting equipment.

Brush Beryllium Co. 205
Beryllium, beryllium alloys, beryllium oxide shapes.

Budd Co. 1159
Gamma-ray radiographic equipment and nondestructive testing devices

Buehler, Ltd. 415
Equipment for preparing metallographic samples.

C

Canadian Government Exhibition Commission 828 and 835
Ores and metals produced in Canada; Canadian-made metal working equipment.

Charmilles Engineering Works, Ltd., Geneva 1768
Machine tools for cutting metals with electric sparks.

Chicago Powdered Metal Products Co. 1597
Machine parts, mass produced by powder metallurgy.

Chicago Rivet & Machine Co. 1464
Automatic rivet setting machines, tubular split rivets.

Chicago Tool & Engineering Co. 1365
Palmgren vises, milling attachments, rotary tables, adjustable angle plates, machine tool accessories.

Chilton Co. 1410
Publisher of *Iron Age, Automotive Industries, Aircraft & Missiles Mfg.*, (business publications).

Chromalloy Corp. 1615
Process for chromallizing iron castings; explosive forming of chromium sheet.

Chromizing Co. 1868
See Metal Improvement Equipment Co.

Chrysler Corp., Amplex Division 1745
"Oilite" self-lubricating bearings, precision parts made by powder metallurgy, and metal filters.

Cincinnati Sub-Zero Products 1756
Industrial equipment for chilling metal and other parts to sub-zero temperatures.

Circo Equipment Co. 1537
Vapor degreasers, agitating washers, steam cleaners, ultrasonic cleaners.

Clausing Division 1550
See Atlas Press Co.

Cleveland Pneumatic Industries, Industrial Sales Div. 1862
"Aire-Motion" pneumatic devices, multi-spindle drill heads, rotary index tables, pneumatic-hydraulic presses, pneumatic presses.

Cobalt Information Center 819
Educational exhibit showing uses of cobalt and its alloys.

Collius Microflat Co. 910
Granite surface plates and accessory items for precise inspection.

Columbus Coated Fabrics Corp. 1662
Colovin-vinyl metal laminates.

Commander Mfg. Co. 1041
Multiple drilling and tapping heads.

Consolidated Electrodynamics Corp. 1468
High-vacuum equipment, vacuum arc furnaces, induction furnaces, packaged pumping systems, components and accessories for vacuum systems.

Cooke, Troughton & Simms, Inc. 215
Microscopes and scientific instruments.

Criterion Machine Works 1264
See Frank Loy & Assoc.

Curtiss-Wright Corp. 1730
Metallic extrusions, forgings and castings; ultrasonic equipment for sub-surface inspection of metal parts.

Curto Co. (AB Curto) 1542
Equipment in continuous line for drawing, straightening and cutting core wire for welding electrodes.

Cutting Tools, Inc. 1845
See Portage Double Quick, Inc.

D

Dake Corp. 1650
Arbor and hydraulic presses; guided platen presses.

Daystrom, Inc. 1649
See Weston Instruments.

Dayton Perforators, Inc. 1016
Standard and special piercing punches, insert dies and insert guides.

Delta Power Tool Division Rockwell Mfg. Co. 1042
Power tools for industry.

de Sanno & Son, Inc., A. P. 1668
Abrasive cut-off machines and grinding wheels.

Detrex Chemical Industries, Inc. 1219
Equipment and supplies for degreasing, sonic cleaning, alkali and emulsion cleaning; chemicals for phosphate coatings.

Detroit Hinge Mfg. Co. 1766
Continuous and butt hinges of steel, stainless, aluminum and brass.

Detroit Testing Machine Co. 739
Testing machines for determining hardness, strength, ductility and other physical properties of metals.

Deutsch Fastener Corp. 1738
Stainless steel rivets and special fasteners.

DeVilbiss Co. 634
Cleaning, coating and painting equipment and systems of every type and size.

DeWalt Division, American Machine & Foundry Co. 1846
Radial arm machinery for cutting wood, metals and plastics.

Diamond Saw Works, Inc. 1344
Band saws of high speed and carbon toolsteel; power saw blades; hand hack saw blades.

Die-Draulic Grip, Inc. 1341
Hydraulic piercing units; adjustable die pad pressure equipment.

Disston Division H. K. Porter Co., Inc. 1456
Industrial cutting tools, saws, files, metal cutting tools generally.

Dixon Crucible Co., Joseph 1369
Metalworking lubricants.

DoAll Co. 620
Machine tools for sawing, grinding and lapping; cutting tools; precision measuring instruments.

Dominion Electrohome Industries, Ltd. 1052
Induction heating equipment.

Dow Chemical Co. 1047
Magnesium metal and alloys; magnesium products; cleaning solvents.

Driver Co., Wilbur B. 1259
High alloys in various forms made to close analysis for the electronic, electrical, chemical and mechanical industries.

Drop Forging Assoc. 1240
Drop forgings for superior service in all industries.

Dry Clime Lamp Corp. 1220
Electric radiant ovens.

DuMaurier Co. 1737
Pocket sized, 20-power inspection and measuring microscopes.

du Pont de Nemours & Co., E. I. Electrochemicals Dept. 1635
Chemicals for degreasing, metal plating and other types of metal finishing.

du Pont de Nemours & Co., E. I. Explosives Dept. 1655
Explosive forming of metals, explosive rivets and other explosive specialties.

E

Easco Products Division 1020
See Electro Arc Sales Co.

Eastman Kodak Co. 1429
Industrial radiography, contour projectors, metallographic equipment, sensitized plates; special photographic devices.

Electric Furnace Co. 1135
Industrial furnaces, atmosphere generators, auxiliaries; exhibits of heat treated parts of difficult shapes or tolerances.

Electro-Alloys Division American Brake Shoe Co. 727
Heat resistant alloy castings.

Electro Arc Sales Co. Easco Products Division 1020
Metal disintegrators, portable nibbling and etching machines, voltage boosters, electrical discharge machines, demagnetizers.

Electromark Corp. 1762
Automatic electrochemical marking system and equipment.

Elox Corp. of Michigan 1516
Method and tools for machining metals by electrical discharges.

Engelhard Industries, Inc. 1430
"Nitroneal" generators and indicators, palladium diffusion unit, purifiers and driers, form roll and laminated materials, slip-ring assemblies, fused quartz and silica ware, borescopes.

Exomet, Inc. 1720
Exothermic materials for lining hot tops and for post heat treatment; insulation.

F

Fannon Products Co., John J. 742

Far-Best Corp. 1549
See Sanford Process Co., Inc.

Fenn Mfg. Co. 1329
Automatic line for wire drawing, flattening, sizing, gaging and spooling.

Fenway Machine Co., Inc. 1054
Portable electric and pneumatic metal-cutting tools; thread and milling machines.

Fischer & Co., H. G. 1317
Automatic electrostatic spray; electrostatic hand gun and transformer.

Fisher Scientific Co. 318
Induction furnace for carbon analysis; "Serfass" hydrogen analyzer; laboratory equipment.

Fiske Brothers Refining Co. 948
See Metal Lubricants Co.

Florida Development Commission 1065
Exhibits illustrating industrial opportunities in Florida.

Foundry 1449
Monthly magazine on production of cast metals.

Foxboro Co. 1340
Scientific, inspection and shop instruments for the metal industries.

Fuller Co., H. B. 1736
"Resiweld" metal adhesives.

Furane Plastics, Inc. 1764
Epoxy plastics.

G

Gaertner Scientific Corp. 320
Precision optical and measuring instruments; instruments for scientific research.

Gas Appliance Service, Inc. 754
Gas fired heating equipment.

General Alloys Co. 548
Stainless steel, heat resistant and corrosion resistant alloy castings and fabrications; heat treating fixtures.

General Blower Co. 848
High-temperature fans; turbo-pressure blowers; industrial fans for handling air and fine material.

General Electric Co. 860
Card-programming system for machine tools; line of computers for industrial data logging, processing and accumulating.

General Fireproofing Co. 1060
Drafting tables, office furniture, steel partitions.

Grand Valley Machine & Tool Co. 1341
See Die-Draulic Grip, Inc.

Gray Co., Inc. 1612
Painting and paint spraying equipment.

Gries Industries 1015

Gries Reproducer Corp. 1019
Small die castings and plastic moldings; standard components; special machinery.

Grotnes Machine Works, Inc. 1856
Hydraulic equipment for expanding and shrinking of metal parts.

Gulf Oil Corp. 1316
Oils and lubricants for the metal industry; quenching oils.

H

Hacker & Co., Wm. J. 420
Metallographic apparatus; microtomes; thermo-apparatus.

Haller, Inc. 1053
Metal hobbing press; briquetting press for powder metal.

Harper Electric Furnace Corp. 1027
Industrial electric furnaces.

Harris Refrigeration Co. 1226
Low-temperature industrial chilling equipment.

Haynes Stellite Co. 527
Division of Union Carbide Corp. Heat and corrosion resistant metals and alloys, sheet, shapes, castings, hard facing materials.

Heath Engineering Co. 1335
"Ultra-graph" precision guidance machines.

Heli-Coil Corp. 1559
Threaded inserts; locking type inserts; thread repair kits.

Heller Machinery Co. 1445

Heller's Son, Inc., E. G. 1445
(Subsidiary of Heller Machinery Co.)

Hevi-Duty Electric Co. 1605
Furnaces for heat treating and metal melting.

High Vacuum Equipment Corp. 1356
Vacuum pumps, furnaces, evaporators, components.

Hitchiner Mfg. Co., Inc. 1735
Precision investment castings.

Homestrand, Inc. 1565
Machine tools.

Hones, Inc., Charles A. 732
Industrial gas burners; heat treating, metal melting and soldering furnaces.

Houdaille Industries, Inc. 1667
See Wales-Strippit, Inc.

Houghton & Co., E. F. 1406
Compounds for lubrication in the cutting and forming of metal and for the surface and heat treatment of metals.

Hupp Corp. 742
Perfection Industries Division.

I

Illinois Testing Laboratories, Inc. 1741
Air velocity and temperature measuring and control instruments; dew point measuring apparatus.

Index Industrial Corp. 1515
Metal working machine tools.

Industrial Equipment News 1797
Monthly magazine.

Industrial Heating 1595
Monthly magazine.

Industrial Press 942
Publishers of business and technical magazines.

Industrial Publishing Corp. 1555
Publisher of magazines: *Power Transmission Design, Precision Metal Molding* and *Welding Design & Fabrication.*

Instron Engineering Corp. 1644
Tensile testing machines; high temperature machine (up to 2200° F.) in air, vacuum or inert atmosphere.

Ionic Electrostatic Corp. 1127
Electrostatic spray equipment.

Ipsen Industries, Inc. 553
Industrial automatic heat treating equipment; vacuum furnaces.

Iron Age 1410
Weekly news-magazine for the metal industries.

J

Janney Cylinder Co. 1561
Centrifugally cast (and finished machined) parts of ferrous and nonferrous metals.

Jiffy Disintegrators, Inc. 1850
Metal disintegrating machines.

Johansson Co., I. O. 1355
Machine tools.

K

Kawecki Chemical Co. 1328
Metals, alloys, chemicals.

Kemp Mfg. Co., C. M. 736
Industrial gas combustion equipment and atmosphere generators; atmosphere dryers; immersion heaters for lead, tin and salt baths.

Kester Solder Co. 842
Solder and soldering fluxes; all types of preformed solder shapes.

King Tester Corp. 419
Portable Brinell hardness tester, Brinell microscopes and adapters.

Kinney Mfg. Division New York Air Brake Co. 1819
Vacuum furnaces, metal evaporators, high-vacuum equipment.

Kolene Corp. 836
Salt bath descaling, cleaning, de-enameling, paint and plastic stripping methods and equipment.

Krouse Testing Machine Co. 1159
See Budd Co.

Kux Machine Co. 1570
200-ton die casting machine with high speed automatic cycling (900 per hr.); automatic power metal compacting press.

L

Laboratory Equipment Corp. 1755
Laboratory equipment, including induction and resistance furnaces with analytic trains for determining carbon, sulphur, oxygen and hydrogen in metals.

La Deau Mfg. Co. 1606
Turnover cradles for handling coils of steel and aluminum sheet and strip.

Lake Chemical Co. 1423
See Markal Co.

Lake Erie Machinery Corp. 1654

Latrobe Steel Co. 1350
Toolsteels, die steels and specialty steels.

Lee Co., K. O. 1023
Grinders (universal, carbide, tool and cutter); expanding mandrels, keyless drill chucks, abrasive wheel dressers.

Leeds & Northrup Co. 836
Heat treating furnaces; electronic temperature recorders and controllers.

Leitz, Inc., E. 426
New research metallograph; "Metallux" phase microscope; dilatometers.

Lempco Industrial, Inc. 602

Lennox Tool & Machine Builders 916
"True-Edge Metlmaster" and sensitive drilling machine.

Lepel High Frequency Laboratories, Inc. 1807
Induction heating equipment, semiconductor equipment, bell-jar vacuum equipment and accessories.

Lilly & Co., Eli 1311
Agricultural & Industrial Products Division
Inhibitor giving bacterial control in soluble cutting oils and synthetic coolants.

Lindberg Engineering Co. 520
Graphite tube furnace (5000° F.); salt bath furnace; Endothermic atmosphere generator with automatic control of carbon potential; carbonitriding furnace with integral quench.

Los Angeles Department of Water and Power 1268
Promoting Los Angeles as a location for industrial plants.

Loy & Assoc., Frank 1264
Cut-off tools, drill adaptors, precision tools and products.

Lufkin Rule Co. 401
Precision tools, dial indicators, measuring tapes and rules.

M

M.B.I. Export & Import, Ltd. 1346
Horizontal optical jig-borer, with semi-automatic positioning.

Machine Tool Manufacturers Affiliates, Inc. 1276

Machinery 942
Monthly industrial publication.

Magnaflux Corp. 865
Eddy current instruments for testing and sorting metallic parts, magnetic or nonmagnetic; test systems for detecting defects in brazed honeycomb or sandwich structures; magnetic particle testing units.

Magnetic Analysis Corp. 319
Magnetizers, demagnetizers, comparators, and testers for magnetic analysis.

Mahr Gage Co., Inc. 316
Precision measuring tools, gages, inspection equipment.

Makepeace Division, D. E. 1430
See Engelhard Industries, Inc.

Malayan Tin Bureau 954
New applications of tin and tin alloys in American industry.

Mannesmann-Meer, Inc. 1867
Powder compacting presses; tube straighteners.

Man-Au-Cycle Corp. of America 1306
See S&S Machinery Co.

Markal Co. 1423
Marking crayons, protective coatings, "La-Co" fluxes and sealants.

Martin Engineering Co. 1739
Industrial vibration inducers.

Martindale Electric Co. 1753
Saws; rotary burs; electrical instruments; dust masks.

Master Bearing Sales, Inc. 1745
See Amplex Div., Chrysler Corp.

Matson Co. 1059
Machining by electrical discharge (and equipment).

McGraw-Hill Publishing Co. 1321
American Machinist (business publication).

Mead Specialties Co. 1324
Air cylinders, air valves, and other air-operated devices.

Mercuria Co. 1469
Automatic hydraulic copy shaper for making electrodes and punches; spark erosion machines.

Metal Improvement Equipment Co. 1868
Shot-peening machine and shot-peened articles.

Metal Lubricants Co. 948
Drawing compounds, cutting oils and coolants; industrial oils and greases.

Metal Powder Industries Federation 533
Powder metallurgy products.

Metals Processing Division 1730
See Curtiss-Wright Corp.

Metal Progress 810
Engineering monthly magazine of the metals industry.

Metal Removal Co. 1835
Carbide burs and rotary tools; grinding wheels.

Metals Documentation Service 810
New ASM service to start in 1960 for providing prompt and up-to-date information on any phase of metallurgical science and engineering.

Metals Engineering Institute 810
Lesson courses for home study, ASM Chapter and in-plant training.

Metals Review 810
ASM monthly tabloid newspaper

Mettler Machine Tool, Inc. 1712
High speed automatic wire straightener, reeler and cutter.

Micrometrical Mfg. Co. 1265
Electro-mechanical instruments (direct reading or recording) for surface roughness or waviness.

Milwaukee Electric Tool Corp. 1757
Shears, drills, grinders, saws.

Mine Safety Appliances Co. 1361
Instruments for atmosphere analysis and combustion control.

Minneapolis-Honeywell Regulator Co., Industrial Division 1426
Industrial instruments and controls.

Minnesota Mining & Mfg. Co. 1048
Barrel finishing mediums and compounds.

Mitchell Radiation Products Corp. 220
Industrial X-ray generators, equipment and accessories.

Montgomery Tool Co. 1744
Steel rule dies; centers for turning split patterns.

Samuel Moore & Co. 1231
Plastic hose and fittings, nylon tubing.

N

NRC Equipment Corp. 1227
High-vacuum furnaces, coaters and components.

Narda Ultrasonics Corp. 1628
Ultrasonic cleaning equipment.

National Carbon Co., Division of Union Carbide Corp. 527
Electrodes for arc furnaces; carbon blocks and other carbon and graphite products.

National Electric Instrument Div. 1430
See Engelhard Industries, Inc.

National Refining Co. 1460
Cutting oils, hydraulic-system oils, drawing compounds, rust preventatives.

National-Standard Co. 1336
Carbon steel, stainless steel, and plated steel wire; flat spring steel; industrial wire cloth; perforated metals.

National Ultrasonic Corp. 924
Ultrasonic cleaning equipment and vapor degreaser; solvents and detergents.

New Hermes Engraving Machine Corp. 840
Pantograph engraving machines.

New York Air Brake Co. 1819
See Kinney Mfg. Division.

Nordson Corp. 1028
Airless spray painting equipment.

North American-Viking Drill Co. 1498
High speed, straight shank twist drills and related items.

Nuclear Materials & Equipment Corp. 1746
Nuclear fuel material; special materials; cathodic vacuum etcher.

Nuclear Metallurgical Enterprises, Inc. 922
Electronic welding gun.

Nuclear Systems Division 1159
See Budd Co.

O

Oakite Products, Inc. 1036
Liquids for drawing, forming, cleaning, phosphate and conversion coatings, paint stripping, rust prevention.

Ohio Crankshaft Co. 1530
Induction heating and heat treating equipment.

Olivetti Corp. of America Machine Tool Division 1022
High-precision cylindrical grinders; sensitive high-speed drill presses.

Olsen Testing Machine Co., Tinius 1616
Tensile and other testing machines and auxiliaries.

O'Neil-Irwin Mfg. Co. 1035

Opto-Metric Tools, Inc. 301
Measuring tools, both optical and mechanical.

P

Pangborn Corp. 1239
Blast cleaning and dust control equipment.

Park Chemical Co. 723
Heat treating and quenching materials and supplies; aluminum brazing salts.

Pathex, Ltd. 1450
Punching and shearing machines.

Payne Tool & Engineering Co. 1716
Dies, stampings and related work.

Penton Publishing Co. 1449
Publications and technical books; *Steel; Foundry.*

Perfection Industries (Division of Hupp Corp.) 742

Perfecto-Peen Division, Aero-Test Equipment Co., Inc. 1659
Glass peening process and supplies for surface reformation and conditioning.

Perkin-Elmer Corp. 312
Vapor fractometer for continuous analysis of furnace atmospheres.

Peterson Machine Tool, Inc. 1767
"Sonoflux" magnetic particle inspection equipment.

Phillips Mfg. Co. 825
Metal cleaning equipment.

PIC Design Corp. 1759
Precision gears, differentials and speed reducers.

Picker X-Ray Corp. 126
X-ray and isotope radiographic equipment and accessories.

Pivot Punch & Die Corp. 959
Perforating punches and dies; "Cone-Lock" retainers and punches.

Portage Double Quick, Inc. 1845
Layout machine; quick-change tools; carbide cut-off tools; micro adjustable tools; end mill driver.

Porter Co., Inc., H. K. Disston Division 1456
Industrial metal cutting tools, saws, files.

Porter Precision Products 1465
Standardized and "Bal-Lok" head-type punches and die buttons, carbide tipped and otherwise; sleeve supported perforators and wire punches.

Power Transmission Design 1555
Technical publication.

Precision Extrusions, Inc. 943
Custom extruded shapes and billets.

Precision Metal Molding 1555
Technical publication.

Presseo Casting & Mfg. Corp. 844
Pressure die castings and permanent mold castings of brass and bronze.

Princeton Division 1730
See Curtiss-Wright Corp.

Protection Controls, Inc. 1718
Safeguards for single-burner and multi-burner heaters; control panels.

Pyrometer Instrument Co., Inc. 1725
Surface, radiation, immersion and indicating pyrometers.

R

Radio Corp. of America 125
Automatic electronic inspection machines and parts; feeders.

Ransburg Electro-Coating Corp. 1250
"Electro-Spray" process equipment, both automatic and manual.

Raymond Corp. 1339
Electric industrial trucks and other materials handling machinery.

Raytheon Mfg. Co. 1811

Relton Corp. 1723
Lubricating and cooling fluids for tapping and drilling; rotary drills for concrete and masonry.

Rexo-Therm, Inc. 1207

Richards Co., J. A. 1211
Steel rule diemaking equipment; bending equipment for sheet metal.

Riehle Testing Machine Division, American Machine & Metals, Inc. 641
Physical testing machines.

Rochester Division 1251
See Consolidated Electrodynamics Corp.

Rockwell Mfg. Co., Delta Power Tool Division and Walker-Turner Division 1042 and 1750
Power tools for industry.

Ryerson & Son, Inc., Joseph T. 627
Steel products; cut-to-order carbon and stainless bars, shapes, sheet and strip.

S

S & S Machinery Co. 1306
Vertical boring mill; lathes; contour cutting band saws; radial drills; cylindrical and surface grinders.

Sanford Process Co. 1549
Equipment for hard coating of aluminum parts.

Scherr Co., Inc., George 1629
Precision measuring equipment, optical and mechanical.

Schmidt, Inc., George T. 1330
Bench and floor model marking machines—hydraulic, pneumatic and hand operated.

Schrader's Son, A. 1625
Control valves for compressed air systems; cylinders; accessories.

Scientific Electric, Inc. 1127
Induction and dielectric heaters.

Scovill Mfg. Co., Inc. 1625
See A. Schrader's Son.

Scully-Jones & Co. 1360
Precision holding tools (machine tool accessories); torque control clutches.

Selas Corp. of America 720
Automatic heat processing machines; combustion equipment; hydrogen generator; hydrocarbon vapor scrubber.

Sentry Co. 1719
Electrically heated high speed steel heat treating furnace with "diamond block" atmosphere control.

Shaw Process Development Corp. 1463
Process for making investment castings of high precision.

Sheldon Machine Co., Inc. 1749
Lathes; variable speed lathe drive with automatic speed selector.

Shell Oil Co. 1642

Sieburg Industries, Inc. 1742
High speed production milling of test specimens or other accurate parts.

Sievert AB, Max 1207
See Rexo-Therm, Inc.

Sinclair Refining Co. 1525
Cutting oils and quenching oils.

Smith Corp., A. O. 1446
Welding machines and equipment; electrodes.

Socony Mobil Oil Co., Inc. 1366
Benefits obtainable by the "Mobil Program for Management."

South Chester Corp. 1640
See Southco Division.

Southco Division, South Chester Corp. 1640
Specialty fasteners for industry.

Spee-Flo Sales Corp. 1815
Spray painting equipment.

Spencer Turbine Co. 746
Turbo compressors, pneumatic conveying machines.

Sperry Products, Inc. 212
Newly designed ultrasonic flaw detection and thickness measurement instruments and automatic inspection systems.

Spitfire Tool Co. 1529

Star Expansion Industries Corp. 1440
Pins, studs, pin-grips, stud drivers.

Starrett Co., L. S. 1256
Mechanic's hand measuring tools; precision instruments; dial indicators; steel tapes, knives, ground flat stock, metal-cutting saws.

Steco Corp. 1748
Cutting fluids, especially adaptable to tapping operations.

Steel 1449
Weekly magazine of news in metals industry.

Steel City Testing Machines, Inc. 1727
Machines for mechanical and physical testing of metals and alloys.

Stimpson Co., Inc., Edwin B. 628
Attaching machines; eyelets; rivets; grommets and washers; snap fasteners; hole plugs; screw machine parts.

Stokes Corp., F. J. 542
Vacuum melting and heat treating furnaces; high vacuum pumps; components for vacuum systems.

Storch Products Co. 928
Ceramic composite tools (magnetic) for holding metals in assembly fixtures and in spot welders.

Struers Chemical Laboratory, H. 119
See Wm. J. Hacker & Co., Inc.

Supreme Products Corp. 1863
"Versamatic" reversable speed reduced drilling and tapping attachments; chucks of various designs.

Surface Combustion Corp. 648
"Power-Convection" system for rapid circulation of atmospheres within heat treating furnaces.

Swift & Co., General Soap Dept. 920
Lubricants and coating compounds.

T

Tatnall Measuring Systems Co. 1159
See Budd Co.

Techline Division, Wheelabrator Corp. 1733
Barrel finishing equipment; wet blast equipment.

Tempil Corp. 225
Temperature-indicating crayons, coatings and pellets.

Texas Co. (Texaco) 965
Metal working lubricants; quenching oils; oil for hydraulic pressure systems.

Thomas Publishing Co. 1797
Publisher of *Industrial Equipment News* and the annual Thomas Register of Manufacturers.

Tin Research Institute, Inc. 815

TOCCO Division, Ohio Crankshaft Co. 1530
Induction heating and heat treating equipment (automatic).

Torsion Balance Co. 960
Hardness testers and analytical balances.

Tree Tool & Die Works 1829
Milling machines and accessories.

Tubular Micrometer Co. 1629
Precision measuring equipment, optical and mechanical.

Tubular Rivet & Stud Co. 1761
Tubular and split rivets; nuts; electrical contacts; rivet setting machines.

Turco Products, Inc. 1724
Strippable coatings; aluminum conversion coatings; phosphate coatings.

U

Union Carbide Corp. 527
See the following divisions:
Haynes Stellite Co.
National Carbon Co.
Union Carbide Metals Co.

Union Carbide Metals Co., Division of Union Carbide Corp. 527
Titanium; chromium; manganese; ferro alloys; deoxidizers.

United Scientific Co. 820
See Unitron Instrument Division

United States Gypsum Co. 1660
Plasters for foundry molds; plastic patterns, jigs and fixtures.

Unitron Instrument Division, United Scientific Co. 820
Microscopes and other optical instruments.

Universal Castings Corp. 1656
Precision, vacuum-cast shapes in brass, bronze, copper and aluminum; high-strength aluminum castings.

V

Valvoline Oil Co. 1460
See National Refining Co.

Vanadium-Alloys Steel Co. 536
Tool steels; special steels for aircraft and missiles; vacuum melted steels; pre-alloyed metal powders.

Vanadium Corp. of America 640
Ferro-alloys; uncommon metals of commercial purity; chemicals for the metals industry.

Vapor Blast Mfg. Co. 1512
Liquid and vapor blast honing machines.

W

Wah Chang Corp. 1560

Wales Strippit, Inc. 1667
Metal fabricator; template drilling machine; punches; dies, notching units; nut fasteners.

Walker Peenimpac Machine Mfg. Division Walker Pump Co. 947
Airless blast for cleaning and peening.

Walker-Turner Division, Rockwell Mfg. Co. 1750
Power tools for industry.

Wallace Supplies Mfg. Co. 941
Bending machines and cutting saws.

Waukee Engineering Co. 1235
Flow meters; washers; compressors; gas-air mixers.

Welding Design & Fabrication 1555
Technical publication.

Wells Mfg. Corp. 1729

Wells & Sons, W. F. 1344
See Diamond Saw Works, Inc.

West Instrument Corp. 1715
Temperature recorders, controllers, indicators; thermocouples.

Westinghouse Electric Corp. 1630
Alloys—electrical, thermo-constant, heat resistant; motors; control devices; gearing.

Weston Instruments, Division of Daystrom, Inc. 1649
Recorders, controllers, thermometers, relays, tachometers, electrical indicating instruments.

Wheelabrator Corp. 1536
(See also Techline Division)
Airless blasting for cleaning, finishing and peening.

Wheelco Instruments Division, Barber-Colman Co. 1455
Potentiometer-type strip-chart and round-chart (circular scale) recorder controllers, with various reset controls.

Wilson, Inc., K. R. 1566
Hydraulic presses, punches, dies and related products.

Wilson Mechanical Instrument Division American Chain & Cable Co., Inc. 953
Semi-automatic microhardness tester; "Twin Testers", reading both Rockwell and superficial scales; Tukon microhardness tester, fixtures, work tables.

Winslow Product Engineering Corp. 1362
Automatic drill point grinder; pneumatic tools.

Overcoming the Producibility Barrier . . .

Producibility, the degree to which a part can be made economically in the quantities needed, is of great significance today to manufacturers of metal goods. The reason: All companies are faced with a severe problem of keeping costs in line to stay competitive. There is pressure from increasing wages and higher cost materials. To compensate for these, manufacturers must look to improved technology for new ideas which will increase the efficiency of their production operations. The following pages, constituting a special "metal month" feature, offer many suggestions for overcoming producibility problems by use of improved metal forming techniques . . . by more suitable selection of everyday metals (p. 129) . . . and by making better use of atmospheres in heat treating and metal processing (p. 144). The ideas suggested cut across many areas – everyday products, aircraft, missiles and atomic energy. Techniques developed to solve a problem in one industry can often benefit other manufacturers.

. . . with improved forming techniques

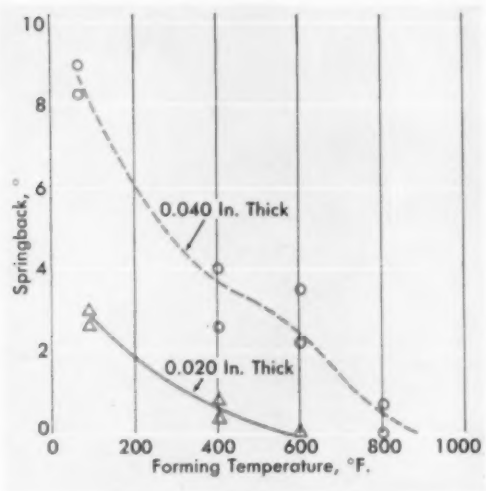
Hot Forming Sheet Metal Parts

*By ALFRED F. HOFSTATTER**

THE GROWING DEMAND for high-strength high-temperature parts made from sheet metal accounts for the increasing interest in hot forming. At Ryan, the method is employed to manufacture parts from 17-7 PH stainless, and commercially pure titanium Ti-75 A.

The forming problems encountered with titanium were initially overcome by using slow strain rates at room temperature. Unfortunately the spring back is never consistent, varying anywhere from 2 to 15°. Because of this, engineers have no basis on which to calculate the overbending spring-back allowance. To overcome the erratic spring back and to avoid the use of slow strain rates, hot forming techniques were developed.

Fig. 1 – Degrees of Spring Back Versus Forming Temperature for Ti-75 A Titanium Sheet. Bend of 90° over a 3 T radius, longitudinal and transverse samples



Define Conditions

The first consideration in working with titanium was to determine what minimum temperature was needed. A series of simple 90° bend tests was made in a closed die, using sheet 0.020 and 0.040 in. thick. Just enough pressure was used to close the die so that each sample was bent to 90° over a 3 T radius. When released from the die, the permanent bend in the sample was measured and subtracted from 90° to derive the spring back. These tests were repeated at various temperatures, resulting in the curves shown in Fig. 1. Elevated-temperature bending was done by heating the die and sample to temperature, applying pressure to form, and holding for 3 min. This is essentially a hot forming and stress-relieving operation combined. Data in Fig. 1 show that virtually all of the spring back is eliminated by forming at 800° F. or above. While this may vary with material thickness, bend radius, or configuration of forming, actual

*Assistant Chief Metallurgist, Ryan Aeronautical Co., San Diego, Calif.

Fig. 2 – Titanium Part Hot Formed in One Hammer Strike. The holding bead will be trimmed off

production experience proves the 800° F. minimum to be realistic.

In addition to spring back, some consideration must be given to mechanical properties of the alloy. To take advantage of its high elongation and low yield strength, it is desirable to form Ti-75 A above 800° F. Thus, consideration of the mechanical properties and the spring back of the alloy establishes the lower hot forming limit at 800° F.

The upper temperature limit is determined by the tendency of titanium to pick up oxygen. Tests show that heating to 1050° F. for a maximum of 2 hr. does not appreciably embrittle the surface due to oxygen absorption. Combining all these considerations, a hot forming range of 800 to 1050° F. was considered satisfactory for the alloy.

Figure 2 shows a typical part which was hot formed with a drop hammer. The majority of parts can be finish formed in one hit; parts requiring deeper draws must be staged (reheated and rehit). This type of hot forming is satisfactory for parts that demand normal dimensional tolerances, but for critical tolerances another method of hot forming has been developed. This method is called hot creep forming.

Hot Creep Forming

Strength-vs.-temperature data on Ti-75 A show that the curve for 10% per hr. minimum creep rate is below the yield strength curve above 750° F. This very low creep strength (4000 psi. at 1000° F.) is utilized to hot form parts accurately. Creep deformation will take place if a part is held under pressure at 1000° F. for a sufficient period of time.

Fig. 3 – Preformed Titanium Part Is Placed in Hot Creep Forming Die. The press applies lateral and vertical pressure to creep form the part to die contour

Fig. 4 – Door Panel Made Entirely From Titanium. All ribs and other internal structures are either hot formed or hot creep formed

The procedure for creep forming a part is first to preform the configuration by any of the conventional methods. The preforming is usually done at room temperature, and little or no allowance is made for spring back. The preformed parts are then placed in a steel die heated to 1000° F. and the die is closed, which allows the part to heat and hot creep form under pressure. The length of time under pressure varies from 10 to 30 min., depending on part configuration.

Figure 3 shows a typical creep forming die. Curved channels or zee sections which are formed on large flat dies lend themselves to this method. All parts made by creep forming have contour and bend angle tolerances. Figure 4 shows the inside of a door panel made from hot creep formed ribs. Because the skin material is extremely thin (0.016-in. thick titanium sheet), the individual ribs must be very accurate to obtain a smooth skin contour. Tolerance requirements of 0.5° for angles and ±0.010 in. to true contour can be maintained on these rib sections by hot creep forming.

The use of elevated-temperature forming of sheet metal parts is becoming more prevalent each year. Hot formed 17-7 PH and titanium are but two examples of how fabricating problems associated with new high-strength materials can be solved. The specific details on the use of die quenching for manufacture of parts from 17-7 PH will be given in next month's issue of *Metal Progress.*

Overcoming the Producibility Barrier . . .

Slip Casting

*By L. M. SCHIFFERLI, Jr.**

SLIP CASTING IS BECOMING increasingly important. Essentially another powder metallurgical technique, it has its own specific advantages and disadvantages, its own process capabilities and its own particular areas of producibility. Unlike hot pressing, it is a room-temperature forming operation; unlike cold pressing, it requires no hardened steel or carbide dies; unlike powder extrusion, it requires no presses.

The process is fairly simple in outline. It consists of five steps: (*a*) preparing concentrated, stable suspensions of finely ground materials in a liquid; (*b*) pouring these suspensions into absorbent molds; (*c*) removing the partially

*Staff Development Engineer, Haynes Stellite Co., Division of Union Carbide Corp., Kokomo, Ind.

dried and solidified shapes from the molds; (*d*) drying completely, and finally (*e*) sintering to increase density and strength.

Many materials have been successfully fabricated by slip-casting methods. Among them are kaolinite, halloysite, montmorillonite, alumina, magnesia, thoria, silica, tungsten, molybdenum, tantalum, stainless steel, molybdenum disilicide, silicon nitride and titanium carbide. This list can be extended by adding mixtures such as chromium-alumina cermets, stainless steel-uranium dioxide cermets, and titanium-zirconia. This listing is by no means complete, since almost all solid materials capable of being reduced to fine powders can be slip cast if economics warrant it.

Powders Need Certain Properties

Materials to be slip cast must have definite characteristics. Particle size is usually less than 325 mesh (44 microns), preferably less than 5 microns average size. This size range is generally finer than required for other powder metallurgy methods. Particle size distribution must be as broad as possible commensurate with average size. Thus, the apparent density of the powder must be high. Spherical or "chunky" powders are required. Fibrous or platelet-type powders are cast with difficulty. Again, solid rather than spongy or porous powders are preferred, although a degree of surface roughness is permissible. Materials must not react with either the suspending medium or dispersing agents. Freedom from absorbed gases or ions is desirable, and soluble impurities must be kept to a minimum.

A variety of liquid suspending media and dispersing agents are required. Water is almost universally used because of its low cost, availability, and low volatility. However, easily hydrated pure oxides such as calcia and magnesia require absolute alcohol. Certain refractory metals, such as tungsten and molybdenum, which may react with water to form complexes, are suspended with less difficulty in liquid cyclic hydrocarbons.

Particle Suspension Is Important

The nature and function of the suspending or deflocculating agent for preparing slips warrants some discussion, since it is upon this one item that the over-all success of the process depends. Materials to be slip cast are usually heavier than water, and would ordinarily settle rapidly. Successful dispersing agents greatly retard this settling either by significantly increasing the viscosity of the suspending medium, or by causing the suspended particles to capture a diffuse ion cloud, resulting in their mutual electrical repulsion. Sometimes, both actions occur. Examples of the first type are alkaline salts of alginic acid, sodium carboxymethyl cellulose and acrylic acid polymer.

Simple, monovalent electrolytes, such as acids or alkalis, can also be used. The primary difference resulting from use of these agents is the viscosity of the slip. Slips made with simple electrolytes are generally much thinner than slips made with the organic compounds mentioned before. As a consequence, casting time (that is, the time required for solidification in the mold) for each type of slip is grossly different. For the former, 10 to 20 hr. is needed; significantly less than 1 hr. is required for the latter. Faster casting slips are necessary for producing thin-walled drain castings, the area where slip casting is especially attractive economically compared to other powder metallurgy methods. On the other hand, organically dispersed and suspended slips are generally better for solid castings of all types.

Patterns and Plaster Molds

Besides the three basic slip ingredients just discussed, the only other materials needed for slip casting are patterns and plaster molds. Patterns are so similar to those used in conventional sand foundry practice that further descriptions are unwarranted. Plaster mold preparation is similar to that used in the ceramic industry, with the exception that "block molds" and "case molds" are rarely made. The working mold is normally "pulled" from the pattern directly. However, as demands for any one configuration increase, this is one area for potential savings. Properly prepared molds are inexpensive to make and, given proper care, will last a long time. Mold cost per piece will be nominal, even though a relatively small number of pieces is required.

Other Equipment

Compared to other powder metallurgy methods, slip casting requires only a modest investment in capital equipment. Only a timer-controlled propeller mixer and scales are needed for plaster mold making. Slip mixing is accomplished by mixers which can impart a high degree of shear to the slip. Liquid handling equipment (such as hoses and pumps), mold drying ovens, and quality control instruments such as a viscom-

Fig. 1 – This Wide Variety of Shapes Can Be Produced by Slip Casting

eter and pH meter are needed for slip casting. The largest single investment goes into sintering equipment because of stringent requirements. Furnaces must attain the necessary temperatures (as high as 3200 to 3300° F. for slip-cast tungsten) and provisions for suitable protective atmospheres (or a vacuum) are needed.

Advantages of Slip Casting

The particular advantage of slip casting is its adaptability. Small or large shapes, either geometrically simple or complex, can be produced with about the same ease. Currently, the process seems particularly well suited for producing a limited number of any one shape. (A production run of several hundred pieces would not result in significantly less cost per piece than a run of about 50 pieces.) If the desired shape is such that more common methods (cold pressing, for example) could be used, and if the quantities involved would result in nominal die cost per piece, such methods would be significantly more economical than slip casting, primarily because of greatly reduced labor cost per piece. Present slip-casting methods are slow compared to other techniques. Consequently, labor costs are higher.

A wide variety of sizes and shapes can be produced by slip casting. Figure 1 illustrates several examples. While some of the pieces, especially the various ring sections, could have been cold pressed, other pieces such as the closed end thermocouple protection tubes and the curved segments in the rear could only have been economically made by slip casting, since the material used is completely unworkable by any conventional metal-forming method.

Because the raw materials are fine grained, slip casting is not ideally suited for producing shapes having sections much over about 1 in. thick. Thicker sections are prone to cracking and also introduce gating and feeding problems. While the solid content of well-dispersed slip is high, usually over 80% by weight, it is only 40 to 50% by volume. Volume contraction of the slip during casting is thus very high. Gates must be large, and castings must be fed constantly to compensate for the liquid absorbed into the porous molds. Thick-sectioned pieces could perhaps be best fabricated by hot pressing, providing graphite molds do not contaminate the final product. Design specifications such as fillets at sharp corners, uniform sections, draft clearances for mold release, and the like are similar to, but considerably more lenient than, those required for other powder methods in general.

Aside from being useful for forming thin-walled complex shapes from powdered materials unfabricable by other methods, the slip-casting process has certain other advantages. Although gravity is the only compacting force, "green" (that is, dried and unsintered) shapes compare favorably with cold pressed compacts and, in addition, are considerably more uniform throughout the piece. Thus, differential densities within the piece, which could result in wide variations

in shrinkage during sintering, are rare in slip-cast ware. This is especially important when producing shapes having large length-to-diameter ratios. Sintered densities, although slightly less than those obtained by hot pressing, compare favorably with densities produced by cold pressing and sintering, and are usually over 90% of theoretical.

A bright future for slip casting as a production process seems assured. The variety of dispersing agents will undoubtedly be extended to permit other materials, having coarser particle size, to be more economically cast into larger sizes. Certain phases of the process, especially casting, can be automated to reduce labor costs. While slip casting will never replace more conventional powder metallurgy methods, it will be used increasingly to supplement them, especially in areas where its low tooling costs and wide capabilities can be capitalized upon. In spite of high development costs (because of the great number of variables which must be calibrated and controlled), a reproducible production process can be evolved for a variety of materials. For those who want more information, a list of references is given on p. 302.

Overcoming the Producibility Barrier . . .

Tube Bending

*By J. E. HAWKING**

TODAY, TUBE BENDING has been developed into a precision metal forming or "drawing" operation, and the tube bending machine has become a highly refined forming tool. The same techniques and machines that bend the sink traps found in every modern home form the solid copper coils of the gigantic electromagnets which explore the mysteries of the proton in the world's largest atom smasher. Our space rockets are packed with precision bent tubing, and our children's school furniture has tubular frames.

Typical bending applications may be cited: Stainless steel tubing, 8 in. in diameter, with a wall thickness of 0.020 in., is bent for use in modern jet aircraft. High-pressure steam boiler tubes, 2.75 in. in diameter with walls 0.150 in. to 0.500 in. thick, are bent on centerline radii of 2.75 in., with thinning of the outer wall held to 5% or less. A machine that develops over 240,000 ft-lb. of bending torque is now forming rolled steel channel into frame units for heavy road machinery. In each instance, bending has reduced costs and improved quality.

New Developments

Designers constantly search for materials of higher strength with greater heat and corrosion resistance. This has required refined bending techniques and equipment. The newest of these, particularly useful on those applications involving extremely thin sections and tight radii, is the "direct-acting pressure die". Figure 1 shows a machine bending a 6-in. tube with a wall thickness of 0.049 in. to a centerline radius of 12 in. The pressure die or "follower block" is operated from a hydraulic cylinder directly in line with the die. This permits the pressure die to "float" slightly to suit minor variations in tube size and wall thickness while preventing wrinkles from forming in the bend. More important, however, the movement and force of this die are governed from an independent hydraulic source that permits instantaneous pressure settings with a direct-reading gage. This simplifies tool setup and reduces setup time.

Figure 2 shows the largest machine ever built to bend thin-walled tubing for aircraft. This machine includes many innovations. Again, the direct-acting pressure die is included. Form die deflection is reduced by using an overhead die support, integral clamping and the in-line pressure die. Adjustments, made from a setup console, establish the predetermined pressures for each particular tube size and radius. The pressure die, clamp die, mandrel extractor, and tube booster assemblies are all adjustable to suit each

*Pines Engineering Co., Inc., Aurora, Ill.

Fig. 1 – Bending Machine Tooled to Form 6-In. Aluminum Tubing. Hydraulic cylinder applies pressure die force directly in line with the tube

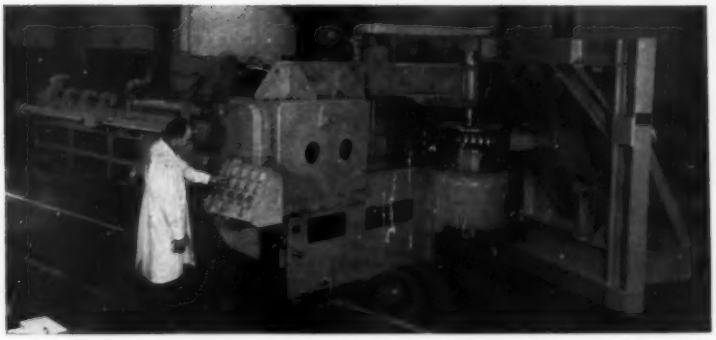


Fig. 2 – Largest Bender Ever Built for Aircraft Work. Operator at set-up console determines die pressure and booster force settings. Multiball mandrel can be seen in form die groove

different tube size and radius. Adjustments are push-button motorized to simplify setup and reduce setup time. The push-button control pedestal regulates machine operations during production. It includes an electric speed control and indicator dial.

Speed can also be controlled by an interchangeable cam plate mounted on the machine. In lieu of the conventional swinging arm, the mammoth clamping mechanism is rotated through the forward bending motion by the form die itself, and returned independently to the starting position to provide clearance for unloading of the bend.

Figure 3 shows a machine for bending high-pressure steam boiler tubing. A hydraulic "booster", tracer-controlled, places the induction heated tube in compression during bending. This reduces thinning of the outer wall to 5% maximum. Tubes from 1.5 to 3 in. diameter with wall thicknesses up to 0.500 in. are bent to centerline radii equal to the tube diameter (Fig. 4). The ability to bend to such small radii permits the designer to get more surface area into a smaller space. Furthermore, control of wall thinning permits him to save at least one and possibly two gages of wall thickness. This development promises application in our space-missile industry where strength and weight are of paramount importance.

Hydraulic Bending Presses

The greatest news in the tube fabricating industry, however, is the recent development of hydraulic bending presses. Through extensive development work in tooling and drawing-pressure controls, bends can now be made to very close radii. In many instances these bends can-

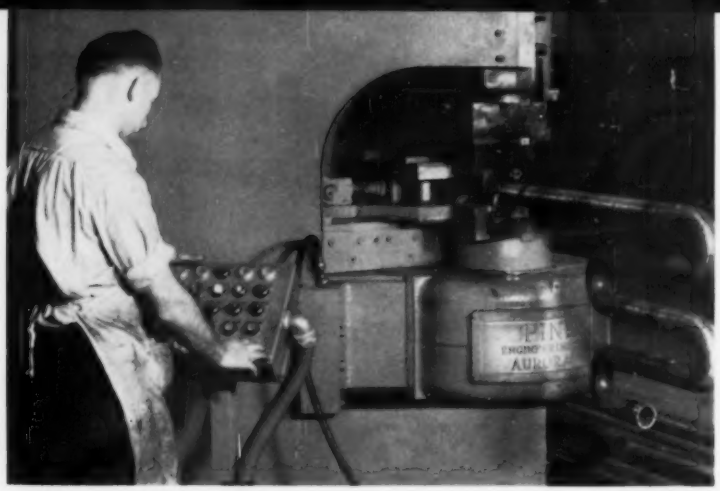


Fig. 3 – Selective Heating From the Induction Unit Allows Boiler Tubing up to 3 In. Diameter With 0.500-In. Wall to Be Bent to a 1 × D Radius With Less Than 5% Wall Thinning

Fig. 4 – Cutaway Sections of Boiler Tube Bends Show How Induction Heat and Booster Force Reduce Wall Thinning to a Minimum in Low-Carbon Steel Tube

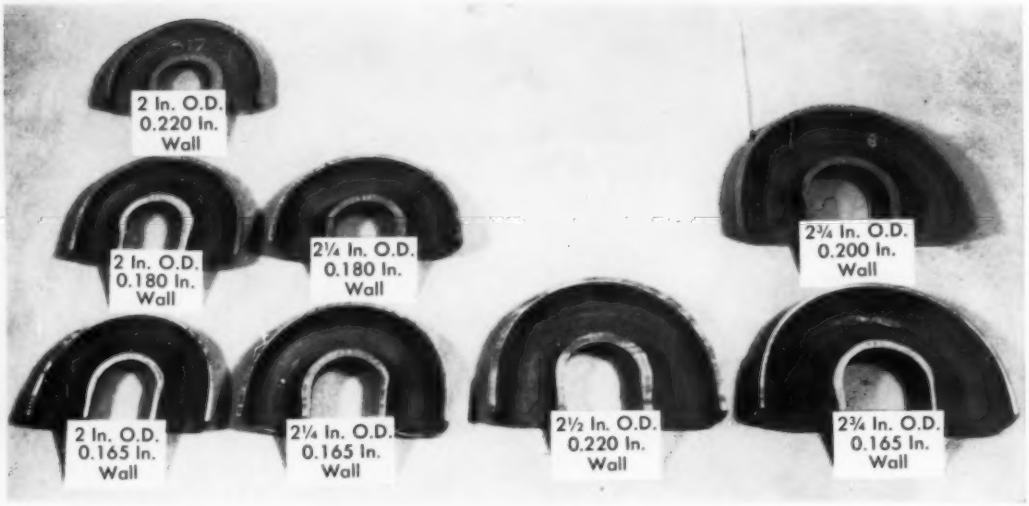


Fig. 5 – Automotive Exhaust Tube Being Formed by "Pass-Through" Bending on 20-Ton Hydraulic Press. Note variety of bend planes and angles

Fig. 6 – Multiple Bending Press Forms Two "U" Frames From Tubing in Single Stroke. Note flattened section that mates with similar piece for welding into a chair leg frame

not be distinguished from mandrel-supported bends by even the experienced eye. Simple automatic indexing of the ram stroke control provides extreme flexibility by changing the angle of bend instantaneously. Multiple forming operations can make bends as fast as stampings, and advanced press design provides clearance around the tooling area to permit forming complex shapes. Figure 5 shows a 20-ton hydraulic press widely used for forming automotive exhaust tubes. The trend in the automotive industry toward larger tubes with heavier walls has even led to the design of a 40-ton capacity press which can form tubes up to 4 in. diameter. This new model, now under construction, will retain the high production speeds of smaller units.

The press shown in Figure 6 is a more specialized model designed to make two bends simultaneously in each of two tubes. It finds its main use in making school, dinette and outdoor furniture. Collapsible dies permit easy loading and unloading of the tubes. Angles of the two bends need not necessarily be identical, and the 2-sec. cycle of the machine permits production speeds up to 3000 bends an hour. The machine illustrated is tooled to form two "U" frames at once, from 1⅛-in. O.D., 16-gage steel tubing. As bends are formed, the press also automatically flattens a section in the center of the "U". A second set of tools forms frames with the flat section on the top of the frame. When the two parts are assembled and welded, they form the legs and seat support for a chair. The flattening operation is an example of how some operations, formerly performed as a secondary production step, can be incorporated into the bending cycle.

Filling the demands of industry for greater production speeds at lower cost is the goal of further development. Automatic machine cycles, automatic loading and continuous operation through programed controls are foreseen in the near future. Whenever metal must be shaped, the possibility of forming, rather than casting or cutting, should be kept in mind, and the advantages of the cold bending process should be considered as a practical production solution.

Overcoming the Producibility Barrier...

Rubber Forming

*J. E. BRODERICK**

RUBBER FORMING of sheet metal parts goes back to the early thirties. Up to that time, sheet metal details, such as nose ribs, contoured frames and the like, were made almost completely by hand; matched metal dies were far too expensive for the number of parts required.

During this period, Henry Guerin of the Douglas Aircraft Co. developed the idea of enclosing rubber in a head which is attached to the ram of a hydraulic press. This design produced more internal rubber pressure and brought about more completely formed parts.

This invention brought significant economies, with no additional cost of tooling over that of the hand form blocks. Parts could be press formed much faster, and the amount of hand work needed to finish the form was consequently reduced. As time went on, many refinements were made in the Guerin process. Each made the process more efficient by reducing the amount of hand work required to produce a finished part.

After World War II, the Martin Co. pioneered in the development of deep drawing with rubber. In this method, the outer area of the metal blank is gripped between rubber and draw plate. As the plate descends, it allows the material to encompass the punch in a controlled uniform flow, thereby producing a deep drawn part free of distortions and wrinkles. The part is completely formed, requiring little or no hand finishing, and tooling is extremely economical compared to draw dies.†

*Senior Manufacturing Engineer, Baltimore Div., Martin Co., Baltimore, Md.

†Several machines employ this method of rubber drawing such as Martin's Marform, Cincinnati Milling Machine Co.'s Hydroform, Convair's Hi-draw.

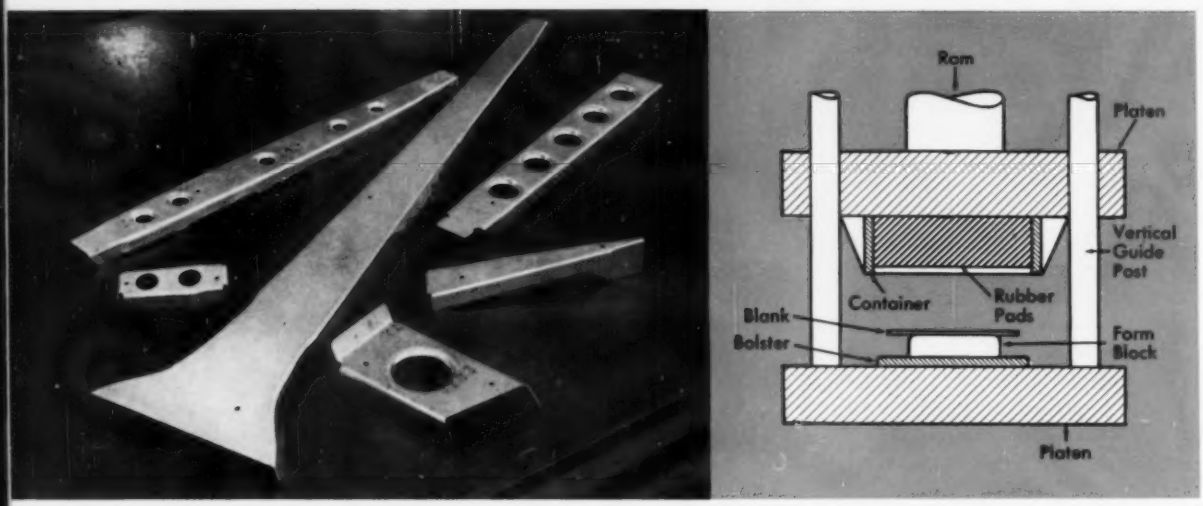


Fig. 1 — The Guerin Rubber Forming Press and Some Parts Made With It. This process is useful for simple parts made from flat sheet

Just as the Guerin process brought about great savings in forming details with simple shapes, the rubber draw method has made the forming of complex and deep drawn shapes far more economical. Before this process was developed, parts that required severe forming were made on draw dies, drop hammers or spinning lathes. All three of these methods were expensive for low-volume aircraft production. For parts that can be formed by the deep draw rubber process, the costly tooling needed for the above methods has been replaced by a male die and a simple draw plate. In addition to the savings in tooling costs, setup time for the process is negligible when compared to that for drop hammer or matched metal dies. Also, where a part may require 30 min. for spinning, or 15 min. for drop hammer forming, the rubber draw method produces the part in about a minute. Together, these advantages make the method especially economical in producing small lots.

Some Other Methods

There are two other processes of rubber forming known as impact rubber forming and the Wheelon process. Considerable experimenting with the drop hammer is being carried out since greater pressure on the rubber gives better formation of parts. This is being done with a drop hammer with a rubber pad and retainer which are attached to the hammer ram.

In an attempt to obtain greater pressures, an explosive charge has been set off in the cylinder of a Ceco stamp (an air-operated drop hammer) to speed the hammer's downward movement. Where hydraulic presses, fitted with rubber pads, cannot furnish enough pressure for particular jobs, the impact method becomes advantageous. However, the relatively small working area of the pad limits this rubber forming method to rather small parts.

The Verson-Wheelon press can apply extremely high pressure over a large working area. This is achieved by a rubber diaphragm contained between the head and bed of the press. The head of the press contains hydraulic fluid that applies pressure to the diaphragm. This, in turn, applies pressure against the blank to form it around the tool.

After rubber forming came into existence, the design engineer was constantly urged by the tool engineer to design parts that lend themselves to rubber forming. The configuration of these parts was not always considered to be the optimum design because the engineer was required to design flutes and cutouts in the shrink flanges. Rubber forming could not shrink the material adequately. Such designs were lower in strength, and this dictated the use of heavier gage material with consequent increase in weight. However, if optimum design had been used, production methods far more costly than the rubber forming process would be needed.

Later improvements in rubber forming reduced the need for hand forming, but only at the penalty of more complex and costly tools. Today, the deep draw rubber method has given engineers greater flexibility in designing stronger and lighter parts.

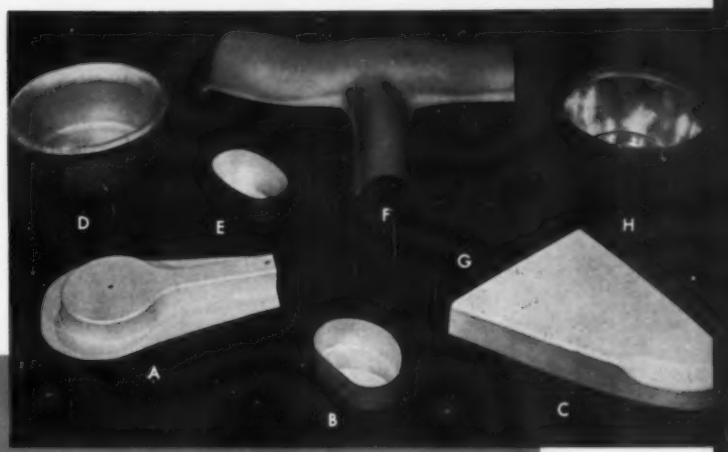
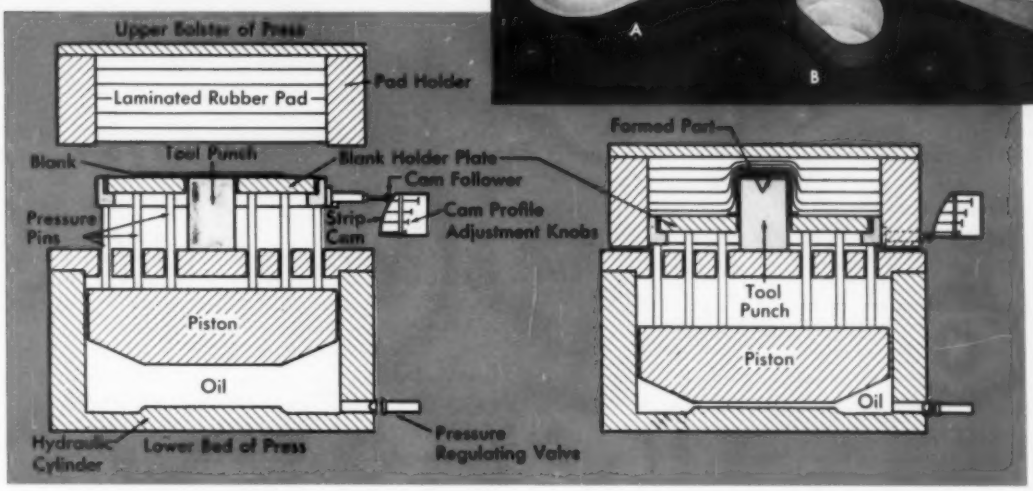


Fig. 2 – The "Marform" Press and Parts That It Makes. Items A, B, C, D and E are of aluminum from 0.008 to 0.500 in. thick. G is also aluminum, but was painted before being formed. H is made from aluminum reflector stock. F is made from Type 321 stainless steel



Until recently these rubber forming methods were used almost exclusively on aluminum alloys. But with the sudden revolution that has taken place in aviation in the last few years a new set of problems now confronts the engineer. With today's demands for vehicles that will fly faster, higher and farther than we had ever dreamed, he is faced with new environmental conditions which aluminum will no longer meet. He is now required to design vehicles to be made from high-strength steels, titanium alloys, and refractory metals.

Extensive research is being carried on to develop techniques for forming these materials. Surprisingly, preliminary results indicate that several of these metals can be formed by the deep draw rubber process nearly as easily as can aluminum, except that more pressure is required. It is surprising simply because the deep draw rubber process was designed principally for aluminum. Since there were no requirements for forming these new materials, the full potential of the process was never explored. To use these new-found potentialities, the tool engineer is applying ideas to this method that are achieving results he never suspected. Ultra-thin foils are now formed free of wrinkles, and difficult configurations are made from high-strength steels with heavy gages. For example, dome-shaped parts, 24 in. in diameter, are being drawn from A.I.S.I. 4335 steel (modified with vanadium) in thicknesses up to 0.375 in. Hexagonal Inconel cups, 3 in. across and 0.002 in. thick, are drawn on a production basis. These parts are containers for insulating material to be used with brazed steel honeycomb structures. In another application, Haynes alloy 25, 0.005 in. thick, was drawn into pan-shaped components that formed the face and edge members of a brazed honeycomb panel. A tolerance of $\pm$ 0.002 in. was consistently maintained on these pans.

Each of the rubber forming methods described above has its place, depending on the design and configuration of the parts to be produced. These methods provide the tool engineer with a broad selection of fabrication techniques. The most economical method for a given quantity, tool cost and span time can thus be chosen.

Rubber forming processes are also proving highly economical for experimenting with the new exotic materials required in the missiles and space ships that are being developed today. As the design engineer utilizes these new materials, that will withstand the stress and heat of the environmental conditions encountered by a vehicle going out into space, he must know the abilities and limitations of each before he can design them into a vehicle. Most important of all, he must know whether the manufacturing department can fabricate components from these materials. It is here that the rubber forming processes are again proving their worth.

If matched metal dies had to be made for each different configuration to determine the limitations of these metals, the cost would be exorbitant. But with the rubber forming processes, many configurations can be inexpensively tested.

Regardless of the pride that may be felt for these advancements, the aircraft industry believes that the full potential of the deep draw rubber process is still to be realized. As metals increase in strength, forming pressures must increase. Some forming experts believe that the near future will bring presses with larger working areas and greatly increased pressures. Both are needed if larger parts of high-strength materials are to be produced.

Overcoming the Producibility Barrier...

Chemical Milling

*By J. L. GAULT, C. C. SHEPHERD and H. H. MULLER**

THE CHEM-MILL PROCESS† uses the technique of controlled chemical dissolution of metal to achieve a specific design configuration. Rate of metal removal depends only on the composition and temperature of the etchant. It is not only independent of physical characteristics (such as hardness or toughness), but the initial shape of the metal part is a restriction only if it limits the uniform contact of the liquid etchant upon the surfaces to be milled. Because metal can be removed uniformly from complex shapes, intricate patterns, and difficult-to-machine materials, this process is now used by most airframe manufacturers.

In describing the applications of chemical milling to airframe designs, comparisons are often made to machine milling. However, the process should not be regarded as performing the same operations in a new manner. Rightfully, it is another fabrication process with definite characteristics of its own. Certain types of parts are ideal for chemical milling, others must compete with machine milling, others are ideal as machined parts, and still others are best produced by combining chemical milling with machining. Chemical milling is most advantageously used when a part has complex contours, complex milled patterns, when very tough or hard alloys are used, when thin sections are required, and when a great deal of metal is removed over a wide area to a shallow depth. In all of these instances, parts can be found that are much less expensive to produce by chemical milling than by machining. Still others may be considered that could only be fabricated by chemical milling.

This process, like other fabrication methods, is influenced by part design, available equipment, and the ingenuity of the processor. While it is recommended that experienced processors be consulted on specific problems, several illustrative examples can be given.

The simplest application is on over-all reduction of sheet or plate where a nonstandard gage is required or where sheet-to-sheet gage variations should be eliminated. Figure 1 shows a typical part treated in this manner. Simple,

*Mr. Gault and Mr. Shepherd are senior research engineers for North American Aviation, Inc., Downey, Calif. Mr. Muller is supervisor, technical services, Chem-Mill and Coatings Div., Turco Products, Inc., Wilmington, Calif.

†Chem-Mill is a registered trademark of North American Aviation, licensed to Turco Products, Inc.

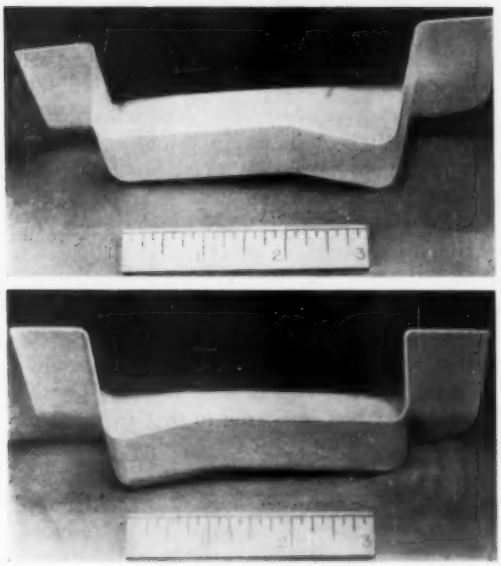
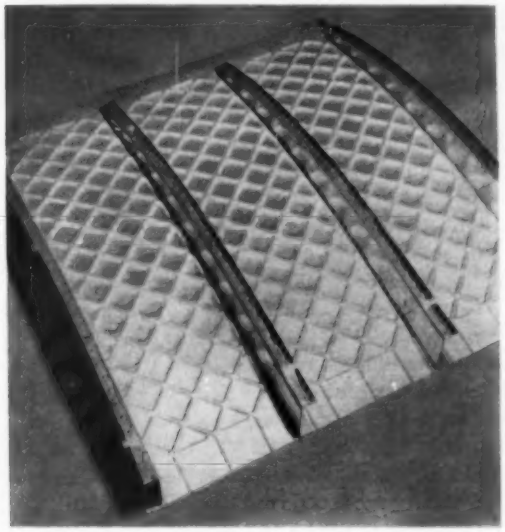


Fig. 1 – Part Before and After Chemical Milling. The original part (below) has an 0.080-in. gage; milling has reduced the gage to 0.032 in.

compound and radial tapers are readily achieved by controlled rates of immersion and withdrawal from the etching solution. Step etches are achieved by sequential removal of predetermined areas of masking material. Both techniques allow simple fabrication of designs with controlled load transfer.* The tapering technique is also used to produce parts of minimum weight by removing crown and linear gage variations from rolled sheet stock.

Fig. 2 – Waffle Pattern Etched Into a Wing Skin. This type of technique can be used to provide minimum weight structures with integral stiffeners



Chemical milling has been widely used to produce pocketed areas and integral land areas on formed and flat parts. The pattern (of the raised land areas and web thicknesses in the pocketed areas) is usually determined by the anticipated stress pattern. Very thin webs may be produced without mechanical distortion. An additional refinement of the pocketing technique is used to achieve minimum weight structures with integral stiffeners (see Fig. 2). These eliminate the need for riveting, seam welding, spot welding, or adhesive bonding of doubler attachments.

Costs can be lowered by "gang-milling" a number of parts on a single sheet at one time. Parts are separated after milling.

A wide variety of casting designs become possible when chemical milling is combined with normal casting techniques. Sand castings, which are relatively inexpensive, can often be used where thin webs and close tolerances are required. This eliminates expensive dies since thin webs need not be precision die cast. Instead, parts are made oversize, and chemically milled for final local or over-all reduction. Essentially, the same approach used on castings also allows design of extrusions and forgings to web thicknesses below those allowed by minimum die clearances. The forging or extrusion can be designed so that the final minimum thickness is obtained by a relatively simple local or over-all chemical reduction. Figure 3 shows a typical example.

Where integral stiffeners, ribs, or cooling fins with thicknesses below the minimums allowed by machining are needed, the rib can first be machined to desired geometric shape and minimum machining thickness. The remaining amount is removed by chemical milling.

The chemical milling industry has expanded to keep pace with the rapid increase in performance requirements of the airframe industry. About five years ago, the process was limited to

*"Controlled load transfer" can be explained by imagining a beam with different cross sections being stressed at one end. If the sections change abruptly (through sharp corners instead of fillets at the junctions, for example), stress raisers are present and the part may break when the load shifts along the axis. On the other hand, if section change is gradual, loads can be transferred through the different sections without danger of exceeding design stress levels. Thus, "load transfer" is "controlled".

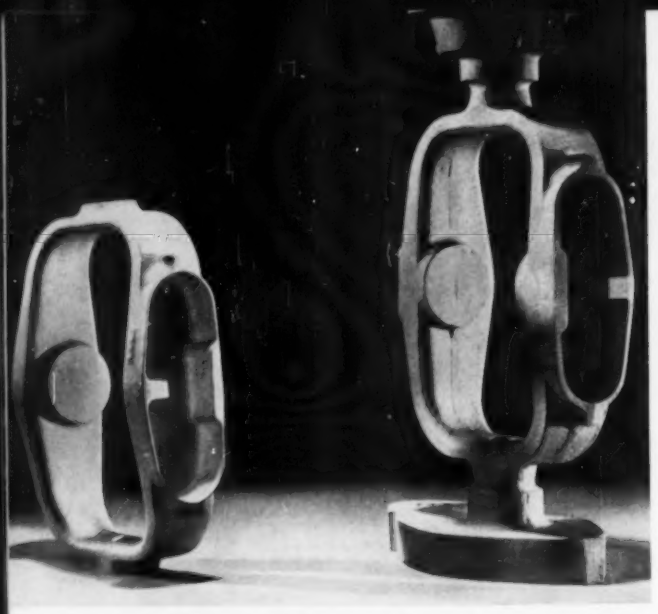


Fig. 3 – This Casting Has Been Reduced by Chemical Milling. This approach can also be used on forgings and extrusions to produce very thin webs

only a few aluminum alloys. Today, due to continued research, it is possible to process a wide variety of metals and alloys. Virtually all aluminum and magnesium alloys can be chemically milled. In magnesium castings, initial surface values of 350 to 600 rms. are reduced to 40 to 100, depending on the alloy and porosity of the casting. Aluminum castings, because of porosity and elements such as silicon, have been much more difficult to mill. At the present time, however, they have been successfully processed in pilot and semiproduction volumes.

A wide variety of titanium alloys are being successfully milled. Surface finishes range from 15 to 80 rms. depending upon the alloy. Most alloys show a negligible increase in hydrogen, but alloys such as 8% Mn pick up hydrogen and thus require vacuum outgassing.

Many steels can be chemically milled. For example, the A.I.S.I. 1000 and 4000 grades, along with Types 300 and 400, have all been investigated. Most of them mill very satisfactorily. The precipitation hardening alloys such as 17-7, 15-7, Types 350 and 355 can also be chemically milled. One of the first alloys milled on a production basis was 17-7, and an appreciable amount of processing experience has been gained over the past three-and-one-half years.

Design requirements for chemical milling of Inconel and Inconel "X" on the X-15 rocket plane led to the development of suitable etchants and processing techniques for high-nickel alloys. High-temperature alloys such as VascoJet 1000, Crucible 56, Hi-Tuf and René 41 can be processed successfully. As demand for these materials increases and present studies continue, the etchants and control procedures will continue to be refined. Finally, exotic metals, such as molybdenum, beryllium, tungsten, columbium and zirconium, have been investigated, and preliminary etching solutions have been formulated. These promise to fulfill future requirements.

The research effort on chemical milling has been directed not only toward applying the process to an ever-increasing number of alloys and metals, but also to increasing process efficiency, economy and design capability. Tooling has been refined, and is now very inexpensive and simple when compared to that required for machining, casting or metal bonding. Furthermore, tools are quickly and easily altered when changes are made in the shape of the part.

Tolerances have been continually reduced. A number of processors now offer production tolerances of ± 0.001 in. on a variety of etch depths, and tolerances of a few hundred thousandths of an inch have been attained on special laboratory test runs.

Masking and Scribing

The most costly and time-consuming steps are masking and scribing. At present, the maskant is applied to a part by dip, flow or spray-coat methods. It is then either air or oven-cured to give it the necessary tensile strength, adhesion, and resistance to the etchant solution. After curing, the areas to be etched are exposed by scribing and removing sections of the mask.

Much time, therefore, has been spent in developing new masks and in improving present masking techniques. Until recently, for example, there was no satisfactory mask for the steel etchants. Now, at least one company has met this requirement, and deep cuts can be made in steel and nickel alloys. The mask can still be hand stripped after etching.

A great deal of work is being done to adapt photosensitive masks to chemical milling. (A satisfactory photo mask would, of course, eliminate the tedious and costly scribing step.) At least one such mask has been developed and is currently being tested by interested companies. At this writing, cuts deeper than 0.300 in. have been successfully made.

Masks have also been developed for application by silk screening. This also eliminates scribing. Both photo masks and silk screen masks are used on very complex (difficult to

scribe) parts. In general, the depth of cut is limited because very thin films are used. The parts should also be flat or nearly flat.

New methods for applying masks that are now available have also been investigated. For example, most masks can be applied by electrostatic spraying. A smoother film, freedom from pinholes, less overspray or waste, and a higher film buildup per coat are the advantages claimed.

In an effort to improve scribing techniques, several companies have experimented with "hot knife" scribing. A heated knife or tip is used to melt the mask, rather than cut it. A soldering iron with a special, sharp tip, the tool from a wood-burning set, or specially developed tools have been successfully used. This method eliminates (or, at least, minimizes) metal scarring, especially in soft metals such as magnesium or alclad aluminum.

A new technique for chemical milling of honeycomb has recently been invented. Now, honeycomb can be contoured to any desired shape. Flat or curved surfaces (even compound curves) are possible. While there are many mechanical methods for shaping honeycomb core, none is as simple or inexpensive as chemical milling in providing unusual shapes or compound curves.

Overcoming the Producibility Barrier...

High-Energy Forming With a Machine Tool

*By RALPH G. MONSEES**

SINCE THE INTRODUCTION of our high-energy forming machine (Model 600 Dynapak) at the 1958 National Metal Exposition, machines with increased ram diameter have been developed and many types of prototype parts have been made. These range from stainless steel surgical pins to gas turbine blades of steel and aluminum bronze, from aluminum billiard cues to reactor fuel elements of uranium. Applications have also included forming of refractory materials such as tungsten and molybdenum at 3500° F. and above. Dynapak machines are now in operation in several leading metalworking plants.

The early model employed a 6-in. diameter ram; succeeding models have been developed with 12-in. (Fig. 1) and 18-in. diameter rams. Dynapak machines are capable of forging, forming, extruding and compacting metals and other materials. In contrast to massive, low-velocity hammers or presses in general use today, high-energy-rate machines take advantage of the phenomenon that even hard, tough, or brittle materials, when dynamically stressed at high unit pressures, exhibit a somewhat hydrodynamic, or quasiviscous, behavior. Materials can be shaped to obtain: (*a*) closer tolerances, (*b*) finer surface finishes, (*c*) thinner sections, and (*d*) reduced radii.

High-Energy Forging

Forgings produced by conventional steam hammers or hydraulic presses for our space-age vehicles or even for general industry leave much to be desired. This is particularly emphasized in studying some 28 conventional steel forgings used in one of America's foremost interceptor aircraft. The forgings ranged in size up to 30 lb. as-received. The record shows:

Total weight of as-received forgings	383 lb.
Total weight after machining	87
Chip weight	296
Average reduction in weight from machining	77%

The cost of machining is obvious but it represents only a portion of the expense. To this must be added the high cost of the material lost in the chips, especially when alloy steel, titanium, or high-temperature materials are used. Long-

*Manager, Dynapak, Convair Div., General Dynamics Corp., San Diego, Calif.

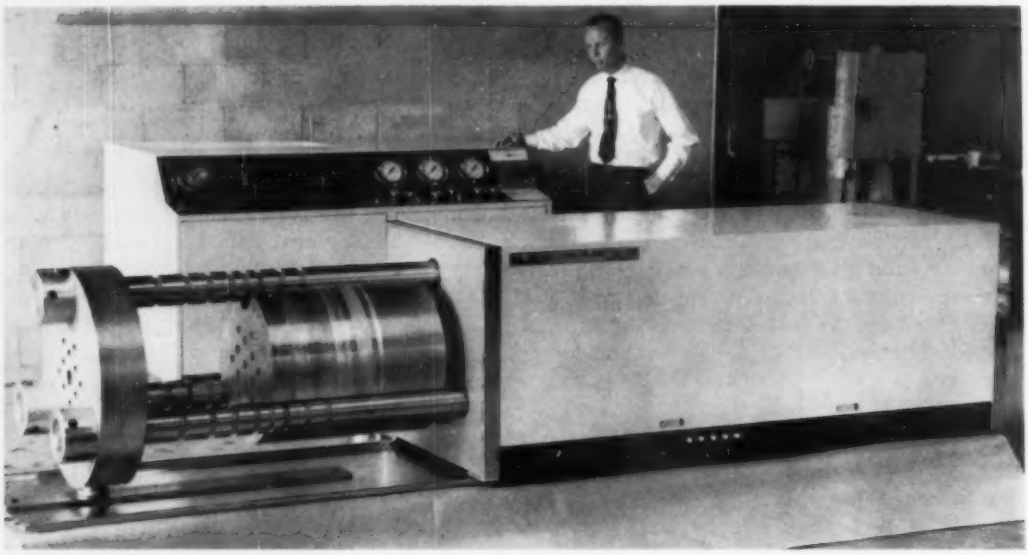


Fig. 1 – High-Energy-Rate Machine Tool With 12-In. Diameter Ram

sought goals in metalworking include production of precision forgings that can be used with but a minor amount of machining – or, ideally, with no machining. High-energy-rate machines offer a breakthrough in this respect. Although these machines are just now being made available to industry, prototype parts formed by Dynapak have required relatively little finish machining after leaving the die.

Figure 2 shows one of many turbine blades forged from various steel alloys and aluminum bronze on a Model 1200 machine (Fig. 1). Aside from a minor amount of flash trimmed from the blade, the part is shown in the as-forged condition. Of particular significance are thin edges of the airfoil section, maximum thickness of the blade, surface finish, and dimensional identity with the die. Figure 3 shows two halves of the split-type die which is used in forming the turbine blade.

High-Speed Forming Cycle

With high-velocity action, material is formed in only a fraction of the time required by traditional methods. This ultrashort forming cycle allows simplified tooling at lower initial cost, reduces die wear, and inhibits growth of scale. In contrast, slow-speed hammer or press forging operations involve relatively long dwell time in the die. Consequently, considerable heat is transferred from the heated billet to the die, a reaction that quickly reduces formability and metal flow. Heating the dies has, of course, helped minimize this problem. However, this makes tooling more complex and expensive. Often this is not practical because die materials have a temperature limitation considerably below that required for best forging conditions.

Although high-energy-rate forming has been discussed mostly in terms of forging, its advantages are generally applicable to other areas of forming, such as extruding and compacting.

Fig. 2 – Turbine Blade Made From Aluminum Bronze With High-Energy Forming Machine. Blade measures 2 in. long by 1.5 in. wide. A portion of the rectangular billet remains intact

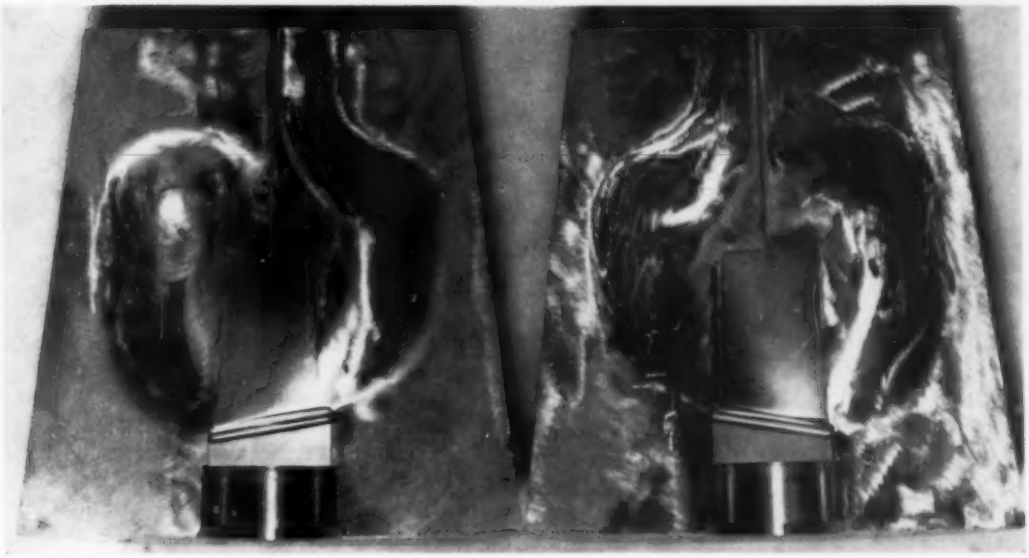


Fig. 3 – Two Halves of the Split-Type Die Used to Form Turbine Blade Shown in Fig. 2

For instance, extrusions of both conventional and high-temperature materials can be produced with an improved surface finish, thinner sections, and precision tolerances.

Refractory Materials

The ultrashort forming cycle, which gives minimum heat transfer between the billet and tooling, provides an effective method of extruding refractory metals such as tungsten, molybdenum, and columbium at optimum temperature rather than at a reduced temperature required by heat characteristics of tooling materials. For a number of commercial metals and alloys, the normal forging temperature is about 80% of the melting point, which is about 3800° F. for molybdenum. Although this is an extreme example, the problem is simply one of degree for other materials. Extrusion test samples have been made from tungsten billets from both arc-cast and powdered metal. In each test, billets were about 1.0 in. diameter by 1.75 in. long and were induction heated to 3500° F. while supported in a Model 1200 machine. Simple extrusion dies made from ordinary toolsteel were used with reduction ratios of 16:1, 10:1, and 5:1. The machine was operated at about one-fourth capacity output with a velocity of 600 in. per sec. Extrusions were made from the powdered billets at reduction ratios of 5:1 and 10:1. Arc-cast billets were extruded with 16:1, 10:1 and 5:1 reduction ratios.

Turbine blades such as shown in Fig. 2 have been traditionally made by a casting process. By applying high-energy-rate forming, however, parts like this can be formed with all the shape and dimensional advantages of a casting, together with the grain, flow lines, and strength realized from the forging process. Aside from the obvious economic advantages, this allows considerable weight reduction in parts – a factor which is of utmost importance to manufacturers of airborne vehicles. Furthermore, the allowable strength of cast parts is in some instances the limiting factor in performance. Thus, by making these new "cast" shapes much stronger than can be done by casting, performance of the end product can be upgraded.

Powder Metallurgy

High-energy-rate compaction of raw metal or ceramic powders or secondary pressing of the compact offers interesting possibilities. Even tually it should be feasible to produce solid (full-density) metal from powder instead of casting conventionally produced billets or ingots. High-energy-rate compaction will allow much larger parts to be produced than is now possible with conventional presses. Also, the high unit working pressures will produce much higher densities with greatly improved physical properties. It is not outside the realm of possibility that parts such as turbine blades could be produced directly from metal powders rather than from billets.

Overcoming the Producibility Barrier...

Hot Extrusion

*By ARTHUR B. TESMEN**

EXTRUSION, the precision process which forms metals under pressure into simple and complex solid and hollow shapes, is coming to the front to satisfy the needs of manufacturers of consumer products and to meet the demands of the aircraft, rocket and atomic industries. In hot extrusion, metal in the plastic state assumes the shape of the die orifice.

Size Limitations

Limitations of extruded shapes with respect to size, weight and shape are determined by the following factors: cross-sectional area, circumscribing circle, length, complexity, thickness, thickness-to-width ratio, extrusion die limitations, and required mechanical and metallurgical properties.

The cross-sectional area is limited by press capacities, which have been considerably increased by presses constructed under the Heavy Press Program. The over-all size of an extruded section is determined by the diameter of the smallest circle which will enclose a given shape, called the circumscribing circle. This diameter controls the die size, which in turn is limited by the press size. Before designing an extruded shape, an investigation should be made as to whether the existing press capacity is satisfactory for the shape required.

Heavy presses, such as the 8000 and 12,000-ton ones, will extrude aluminum shapes which can be enclosed in circles up to about 25 in., weighing up to 2500 lb., and over 110 ft. long. Steel and titanium shapes, whose cross sections fit into a 22-in. diameter circle, can be extruded on a 12,000-ton press. These limitations can be circumvented in some instances by slitting and straightening circular extrusions.

The minimum cross-sectional area which can be extruded on a press of given capacity depends upon the pressure required to overcome the metal's resistance to flow. Pressure, in turn, is determined by the extrusion ratio (ratio of the billet and extrusion cross section), the nature of the alloy and complexity of the shape being made. While most common extrusion ratios range from 15:1 to 50:1, certain intricate and thin sections have been extruded at ratios as high as 500:1. Extrusion ratios below 15:1 are seldom used (unless extrusion is an intermediate working step) because insufficient working may result in poor mechanical properties. Data below for steel and titanium are a rough guide for extruding metals of high melting point.

METAL	MINIMUM CROSS-SECTIONAL AREA
S.A.E. 1020	0.40 sq. in.
Type 410	0.45
Types 304, 321, 347	0.50
Type 316	0.60
A-286	1.25
Titanium alloys	0.50

Section Thickness and Tolerances

Thickness limitations are related to the size of the cross-section; increase in the circumscribing circle size makes it more difficult to force the metal through thin die openings, especially if the shape has adjacent thick and thin sections. As a general rule, thicker walls are required with increased section size. Thickness limitations also depend upon the flow (or yield strength) of the alloy, extrusion ratio, and complexity of shape.

Section thickness may vary from about 0.040 in. to several inches in aluminum and magnesium and from a minimum of 0.145 in. in plain carbon steels, 0.180 in. in some stainless grades, and 0.150 in. in titanium alloys. The relative thickness of adjacent members plays an important part in extrudability of various sections. The

* Metallurgical Engineer, Loewy-Hydropress Div., Baldwin-Lima-Hamilton Corp., New York; Consulting Editor, *Metal Progress*. The author acknowledges assistance of the following in preparation of this article: Air Materiel Command, U.S.A.F.; Babcock & Wilcox Co.; Chase Brass & Copper Co.; Climax Molybdenum Co., Div. of American Climax, Inc.; Curtiss-Wright Corp.; Dow Chemical Co.; Harvey Aluminum, Inc.; Loewy-Hydropress Div., Baldwin-Lima-Hamilton Corp.; Reynolds Metals Co.; Wolverine Tube Div., Calumet & Hecla, Inc.

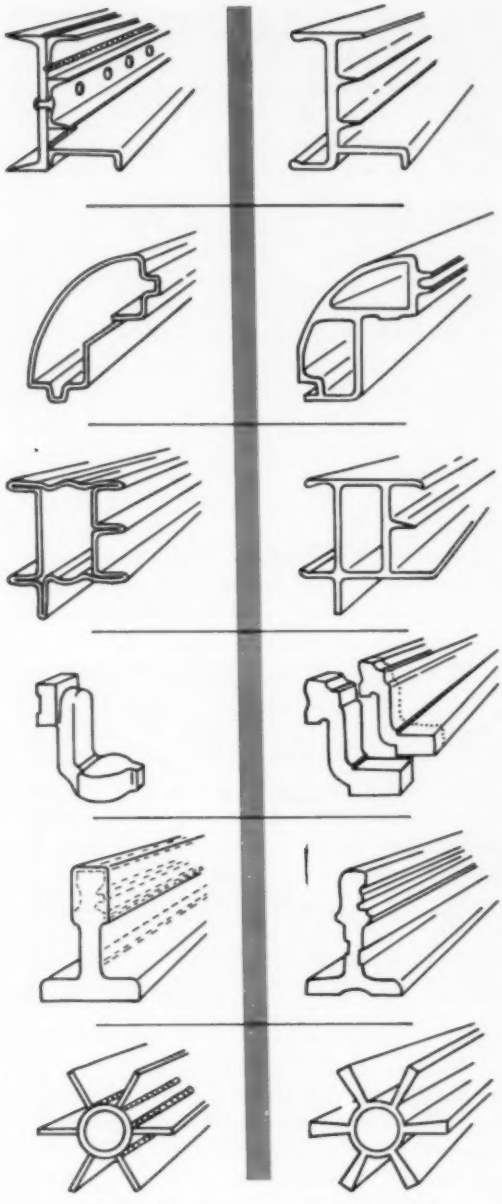


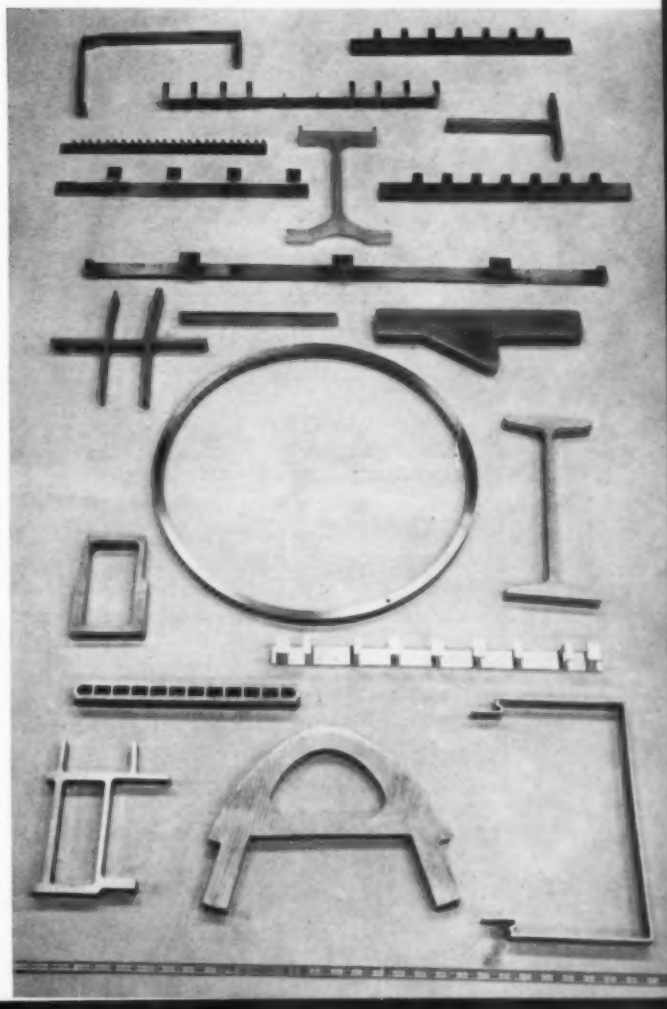
Fig. 1 – How Extrusion Replaces Other Forming Methods

permissible ratio of thickness to width depends upon the alloy. For example, the minimum thickness for a shape about 8 in. wide is 3/32 in. for aluminum alloys 3003 and 6003, but ⅛ in. for 2014 alloy for a press of given capacity.

Although extruded shapes minimize and often eliminate the need for machining, they do not possess the dimensional accuracy of machined parts. The tolerances of any given dimension vary somewhat depending on the size and type of the shape, and relative location of the dimension. For example, the 3-in. web of a 3 × 0.258-in. aluminum channel could vary from 2.976 in. to 3.024 in., but when measured at the toes of the 1½-in. deep flanges, the permissible variation on the 3-in. dimension can be 2.952 to 3.048 in. Detailed tolerances covering straightness, flatness, twist, and cross-sectional dimensions such as section thickness, angles, contours, and corner and fillet radii are given in handbooks published by extruders. Minimum fillet radii of 0.125 in. for steel and 0.188 in. for titanium are produced by some extruders, and corner radii are minimum 0.031 in. for steel and 0.055 in. for titanium. Angle tolerances of 2° or less can be held for aluminum, steel, and titanium.

Although the extrusion engineer has consider-

Fig. 2 – Cross-Sections of Large Aluminum Extrusions Produced by Harvey Aluminum, Inc. Applications include missile body sections, truck trailer floors and doors, airframe structures, curtain wall components and signs



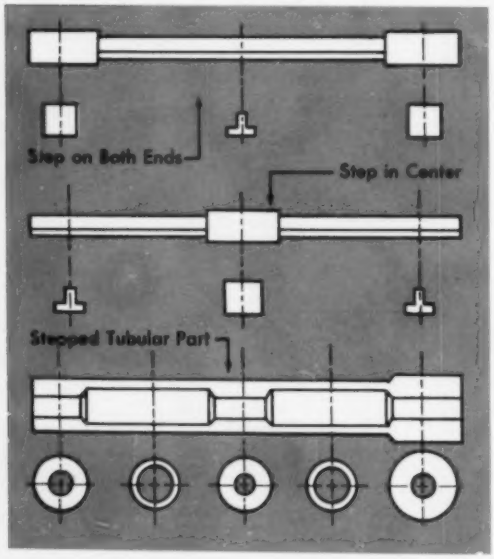
able freedom in placing metal where it will be most effective, he should avoid certain features to keep costs down and to maintain tolerances. While many asymmetrical shapes can be extruded, probably the most important factor in the extrudability of a shape is symmetry. Other important considerations are average and minimum thickness, cross-sectional area, surface quality, and mechanical properties.

Some Do's and Don't's

Hollow and semihollow shapes cost more than solid shapes and they usually cannot be extruded with as thin sections as solid parts. They are more readily producible when wall thickness surrounding the voids is uniform. However, a one-piece hollow shape is usually stronger than a built-up shape. Its assembly cost is lower, and mating fits and tolerances of component shapes are not a factor.

Adjacent section thicknesses should be as nearly equal as possible to permit uniform metal flow through the die. Grooves should be wide and shallow to prevent undue pressure and heat on the die area forming the groove. Thin-walled shapes with large circumscribing circle are difficult to straighten. In shapes with varying section thickness, the length of thin protruding legs should not exceed ten times their thickness. Semihollow shapes requiring long thin die tongues should be avoided; for best extrudability the tongue length should not exceed three times its width.

Fig. 3 – Stepped Extrusion Planned for Future Production



Precision extrusion, a process which combines extrusion with cold drawing, results in very close cross-sectional tolerances. A typical application is a magnesium extrusion, produced to ± 0.002-in. tolerance on all dimensions for an automobile transmission stator blade.

Among proposed missile extrusions is a 13½-in. diameter tube with 0.100-in. wall, integrally extruded, including the external ribs to mount the fins. This design would eliminate longitudinal welding of tubes and spot welding of the external ribs.

Rectangular Container Extrusion

Demand for wide, thin, ribbed panels by the aircraft, transportation, and architectural industries has resulted in the rectangular container extrusion. The conventional extrusion container has a round bore and cylindrical ingots are used. A rectangular container has a rectangular bore

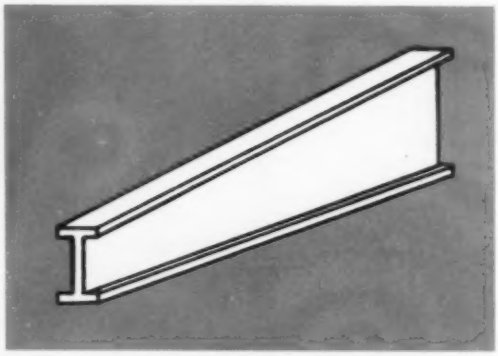


Fig. 4 – Extruded I-Beam, Longitudinally Tapered

and slab-shaped ingots are used. This method effectively increases the available press capacity, making it possible to extrude wider, thinner and flatter shapes. In recent experiments carried out by Loewy-Hydropress Division (sponsored by Air Materiel Command), the feasibility of extruding flat panels from 7075 aluminum alloy in 18-in. widths with thicknesses as low as 0.035 in., and in 9-in. widths, with thickness of 0.023 in., was established. Application of this method to larger presses would extend the maximum as-extruded width to about 42 in.

Stepped extrusions permit design of parts with integral connecting lugs; with two, three, or more sets of steps; with internally and externally stepped tubes (Fig. 3). Steps can be placed at

either end of the tube or in the center. Extrusion of longitudinally tapered sections, such as shown in Fig. 4, and of tapered tubing, is possible by special split die and moving mandrel techniques.

Aluminum extrusions are being widely applied in building construction for curtain walls, window and door frames, building trim, ladders, scaffolds and structural sections. The transportation industry is using them for truck and trailer roofs and side rails, side and bottom sills, floor beams, tailgate sections, and roof bows. Standard interlocking extruded sections are used in truck and trailer flooring, walls, and railroad boxcar sections. Extruded aluminum tubing and sections are employed in furniture and appliances for trim and functional purposes and in automobiles for grilles and trim. The aircraft industry employs aluminum extrusions as basic strength and stiffening members – wing spars, spar caps, struts and ailerons.

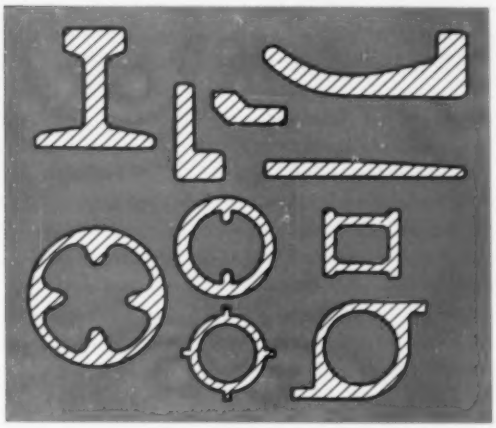


Fig. 5 – Extruded Steel Sections Which Are Difficult or Impossible to Roll

Future trends indicate that the electrical industry will use aluminum extrusions for substation and transmission tower structural components, particularly under corrosive conditions where its life will be longer than that of galvanized steel, and for transmission poles with longer life than wooden poles. Other electrical applications include cable, cable sheath, splicings, fittings, busbar and conduit.

Magnesium extrusions are used in aircraft and missile structures; military and commercial vehicles; materials handling equipment; concrete pouring forms; tools, jigs, and fixtures; radar and electronic devices; portable shelters; and anodes for cathodic protection of water heaters. Missile body tubing, helicopter blades, and stator blades for automatic transmissions are some promising applications.

Practically all common steels have been successfully extruded. Alloys such as 4340, 4130, 8620 and most stainless steels are readily pro-

Where to Use Extrusions

Engineers who specify extrusions should consider the following advantages:

- Configurations difficult or impossible to roll in aluminum or steel or other metals can be extruded. Certain alloys, such as Type 440 C steel, considered unpierceable and formerly unavailable as seamless tubing, are readily extruded.
- Elimination of "bits-and-pieces" manufacture since integral complex shapes can be extruded.
- Shapes can be designed to facilitate joining to other members by adding or taking off flanges or ribs, or by increases or decreases in thickness across part of the section.
- Machining can be reduced or eliminated since extrusions can be designed closely to the final required shape. Steel and titanium extrusions can be cold drawn to improve surface finish and to tighten the tolerances if required.
- In view of low cost of extrusion dies, it will often pay to design special extruded sections to meet the specific requirements, rather than to sacrifice efficiency by using available standard rolled sections. Extruded sections can be "tailored", economically, to meet the needs of the design from the standpoint of strength and stiffness.
- If running design changes are anticipated or desirable, or if parts are urgently required, low-cost dies, short lead time, and the ability to produce in small quantities make extrusion economical.
- Some complex shapes can be more economically extruded than cast or forged.
- Improved transverse properties and better fatigue resistance of some high-melting-point extrusions are significant.

duced; current development work has as its goals extrusion of A-286 heat resistant alloy and H-11 type toolsteels to thin, close-tolerance aircraft shapes.

Civilian applications for carbon steel extrusions include parts for business machines, electrical equipment, automotive products, and air conditioning equipment. In some instances the parts are impossible to produce by rolling (Fig. 5), or they replace weldments, castings, forgings, or parts machined from bar stock. Their mechanical properties are superior to castings and roughly comparable to forgings.

Extruded titanium tubing is making a comeback in applications requiring retention of strength in the medium elevated-temperature range and those needing corrosion resistance. Hydraulic line tubing in jet engines and corrosion resistant piping in refining, chemical and processing industries are promising applications. Others include heat exchangers, autoclaves, and fittings.

While molybdenum extrusions are just beginning to be utilized as such, development of this metal has been enhanced by employing extrusion as a primary working step. Work is being done on commercial methods for extruding beryllium, and progress in nuclear technology has stimulated extrusion methods for zirconium, uranium and hafnium alloys. High-quality thin-walled zirconium tubing (3 in. O.D.) has been extruded in lengths up to 24 ft., subsequently reduced to final size by cold reduction.

Co-extrusion of two or more metals has been employed to fabricate zirconium-clad uranium fuel elements with integral zirconium end seals. The extrusion billet, consisting of uranium or uranium alloy core, is surrounded by a zirconium or Zircaloy-2 sleeve. The core and cladding components are enclosed in an evacuated, sealed copper can and extruded. Zirconium and Zircaloy-2 have been successfully clad to unalloyed uranium by this method, and to several alloys consisting of uranium with such additions as 2% Zr, 10% Mo, 4% Si, 5% Zr or 1½% Cb.

Overcoming the Producibility Barrier...

*Metal Spinning**

SPINNING IS THE PRESSURE FORMING of metal on a rotating chuck or die. The forming is done by application of pressure by a roller or spinning tool on the metal piece while it is being rotated in a spinning lathe. Two types are conventional spinning and displacement spinning. Conventional spinning involves forming of the metal back along the chuck. The area of the blank must be about equal to the shell area and the shell thickness remains constant. Displacement spinning involves an ironing out of the metal back along the chuck. Here a smaller and thicker blank is used so the difference between the blank and shell areas is equalized by thinning out a portion of the thick blank.

Practically all metals that are available in sheet form can be spun. Hand spinning can be done on aluminum alloys up to ¼ in. thick, low-carbon steels and brasses up to 3/16 in. thick, and stainless steels up to ⅛ in. thick. Although most common metals are cold spun, it is sometimes advantageous to hot spin to reduce the force required. Molybdenum, titanium, and magnesium alloys are usually spun at moderately elevated temperatures – somewhere between the range of cold spinning and true hot spinning.

The spinning blank can be either a flat disk, a piece of tubing or a welded tubular or conical section. The blanks may have sheared edges but they must be cut cleanly. Rough edges should be ground or machined smooth before spinning to avoid cracking. Suggestions on shape considerations for spinning are given on p. 121.

*Adapted in large part from "Production Design Handbook", Materials and Equipment Div., Air Research & Development Command, U.S.A.F.

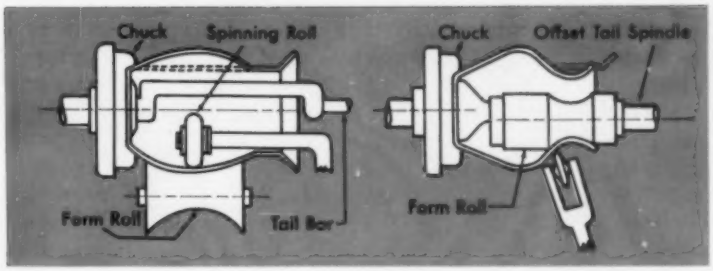


Fig. 1 – Typical Setup for Internal Roll Spinning

Conventional Spinning

Chuck spinning, the most common method, refers to spinning of open shapes with no re-entrant contours. Here the shape can be produced in tiers and by one or more regular spinning operations. Internal roll spinning is a method for spinning re-entrant shapes, such as bulges and necks. The chuck and tail bar are on the same center and the roll is offset to make contact with the shell wall. The method results in higher production speeds since the piece can be quickly removed from the roll without taking the tool apart. (See Fig. 1)

Displacement Spinning

In the Hydrospin process (machine made by Cincinnati Milling Machine Co.), the blank in the form of a metal disk is rotated at high speed while two opposed rollers force the material onto a rotating mandrel. A major use of Hydrospinning is to make dome-shaped contoured aircraft components. These parts were previously produced by fabricating two sections, then welding them together. It is used also in the manufacture of high-temperature parts such as jet exhaust cones and engine parts. The process gives extremely strong parts with maximum resistance to fatigue failure. The metal undergoes a shear deformation which greatly elongates the grain structure, resulting in work hardening of the metal with an increase in tensile strength.

In the Floturn process (machine made by Lodge & Shipley Co.), the metal is displaced parallel to the centerline of a part in a spiral manner. This spiral displacement is done by flowing the metal over a mandrel using a roller that is actuated by mechanical or hydraulic forces. In spinning, a blank considerably larger than the finished piece is used. Then, using pressure, the blank is folded in a circular manner, using a hard tool against a round mold. This requires considerable skill by the operator.

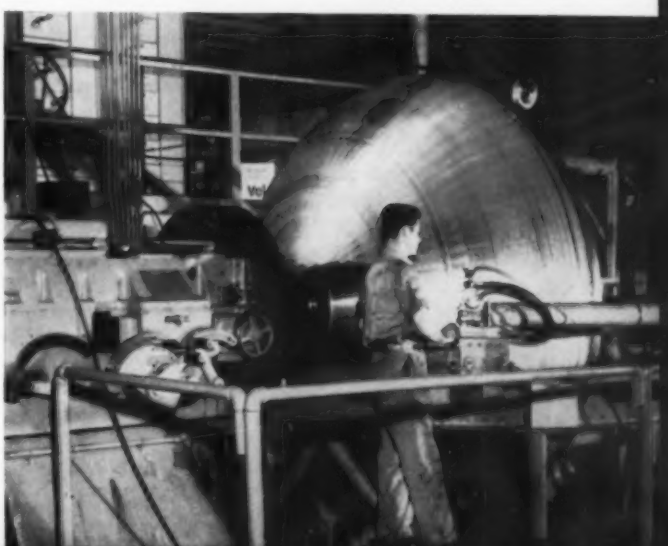
In the Floturn method, the blank diameter is the same as that of the finished part, but the thickness is heavier and the additional metal provided by this heavier thickness is flowed into the extended shape. The machine controls all operations, and parts are produced to uniform accuracy. Parts have high strength and hardness with good surface finish. Tooling cost is low. Typical tolerances which may be held are 0.002 in. on wall thickness, 0.002 in. on I.D. up to 6 in., 0.003 in. on I.D. over 6 in. and 0.005 in. on length.

Power Spinning From Preforms*

Power spinning, such as has been described in preceding paragraphs, is a production process capable of making parts with high strength, good surface finish, close tolerances, and freedom from inclusions or other hidden flaws. Often it is a less costly means for producing parts with prop-

*This section is based on information supplied by engineers at Commercial Shearing & Stamping Co., Youngstown, Ohio.

Fig. 2 – This Fuel Tank Head – 105 In. in Diameter – Is one of the Largest Thick-Walled Vessels Ever Spun. Made of 5086 aluminum alloy, the part was spun from a blank 139 in. diameter, 7/16 in. thick by Missile-Air, a Division of U. S. Chemical Milling Corp.



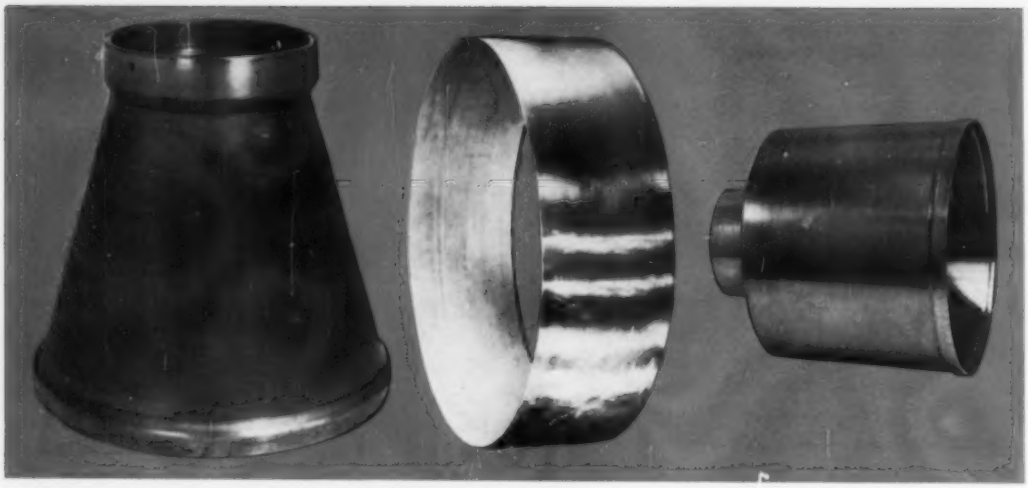


Fig. 3 (Left) – This Straight-Side, Tapered-Wall Rocket Cone Would Have to Be Hogged From a Large Forging if It Were Not Power Spun. A flat blank, 19 in. diameter and 1 in. thick, is preformed which provides for the shape of the thick sections at top and bottom and allows for tapered wall thickness. A single power spinning operation begins just below the top thick section and ends just above the bottom thick section. (Right) – To produce this part a cup-shaped preform is made in a press from a flat blank of Hastelloy C, 14 in. diameter and ⅛ in. thick. After power spinning the basic bucket shape, the press-formed cup is welded to the bottom, the flange is faced and groove and holes are machined. Use of a highly polished mandrel gives I.D. finish of 10 micro-in. (Center) – Thin-walled aluminum band requiring concentricity within 0.001 in. and mirror finish O.D. is easily power spun from press drawn aluminum cup

erties which would otherwise require special tubing, extensive machining of forgings, high-alloy steel, or heat treatment. Where hard-to-machine alloys are required, they may be power-spun as readily as carbon steel.

While a variety of conical, tubular, and curvilinear shapes may be power-spun directly from flat sheet or plate, there is a limitation on non-tubular designs produced in one pass from flat stock; wall thickness will be fixed by the angle the wall of the final product makes with the horizontal, and this angle normally cannot be less than 15°. This limitation to an included angle of 30° is fixed by the maximum practical reduction per pass and is substantially the same for all ferrous and nonferrous metals. It can be overcome by producing the final shape in more than one power spinning pass.

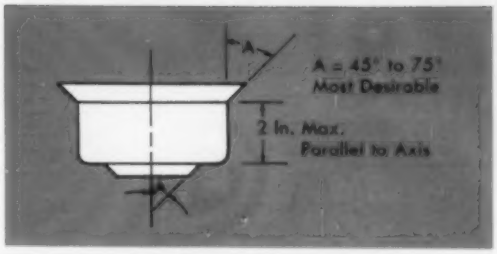
Methods for Preforms

The final power spinning pass may be considered as a single pass made on a blank which, instead of being flat, has been preformed to an intermediate shape. The preform may be produced by prior power spinning passes, or it may be a forging, stamping, casting, or weldment. With a preform, limitations on wall angle of the final part and wall thickness are substantially eliminated. Suitable variations in wall thickness of the preform will give the wall thickness needed (even varied wall thicknesses) in the final part. Preforming makes it possible to produce the desired final shape in a single power spinning pass.

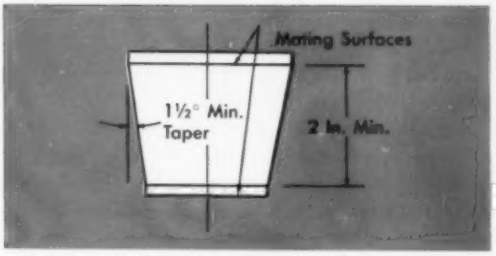
Proper preparation of the preform also assists in obtaining close tolerance of wall thickness and fine surface finish on the final part. In general, power spinning will improve the O.D. surface finish of the blank, and reduce its thickness variations, by a factor of two. Inside diameter surface finish is improved more than this because spinning is done on a highly polished mandrel. However, this improvement is not enough to permit power spinning to turn rough stock into highly finished, accurate parts. To secure wall thicknesses and dimensions within narrow limits, and to produce low micro-inch surface finishes, requires a suitable degree of accuracy and finishing in the preform. For example, to obtain tubing with an I.D. finish of 20 micro-in., one should start with a thick-walled tubular blank with a bored and honed I.D.

Such extensive work to produce a preform makes power spinning sound like a complex and expensive process. Contrasted to simple hand

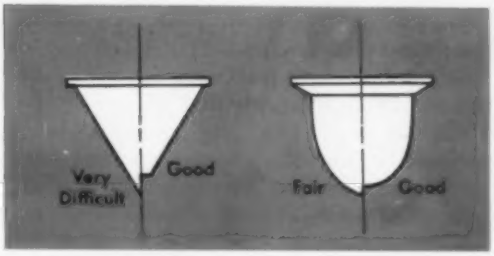
Shape Considerations in Spinning



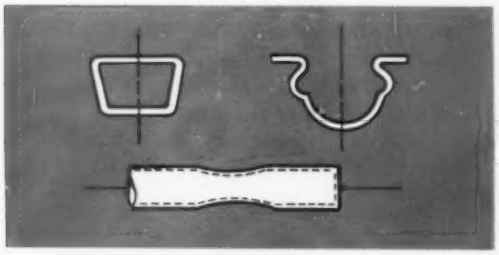
Minimize Number of Surfaces Parallel to Part Axis



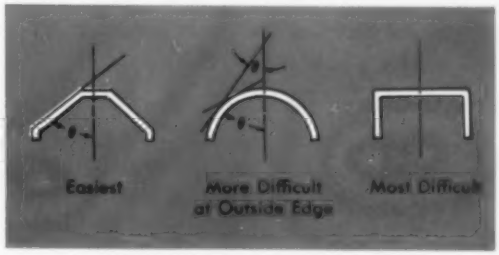
Use 1½° Minimum Taper on Parts Deeper Than 2 in., Except for Mating Surfaces



Maintain a Small Flat at Bottom of Part Where Possible. Diameter should be at least 10% of over-all diameter



Avoid Re-Entrant Contours



Difficulty Increases as Angle Between Surface and Axis Decreases

spinning, it is. But it is useful in place of other production methods which would be even more complex and expensive. Another advantage is that it permits use of less costly raw materials. For example, a heavy conical shape (Fig. 3, left) formerly hogged from a large forging, is power spun with considerable savings. (Commercial Shearing & Stamping Co., which produced parts illustrated in this section, uses slightly modified Cincinnati Hydrospin equipment for power spinning.)

Also produced by power spinning is a bucket of a tough superalloy (Fig. 3, right). If produced by conventional means, this bucket would require several setups in different machine tools and cost would be boosted by the difficulty of machining the alloy.

Often, the ultimate tensile strength of steel can be doubled, and its yield strength tripled, because of the cold working in power spinning. This may permit use of a carbon steel where an expensive alloy had been considered necessary. This improvement in physicals without heat treating is especially useful in long and thin-walled shapes which would be difficult to heat treat without distortion. Also, tubes and cylinders are produced which have very thin walls in relation to their diameter and thus would be difficult to machine to obtain concentricity of O.D. and I.D. and to avoid bow.

Overcoming the Producibility Barrier...

Cold Extrusion

*By ELLIOT J. EPNER**

A SHIFT IN TEN YEARS from products which were 90% government, mostly ordnance components, to our present production of 90% commercial parts is the experience of the Heintz cold extrusion department. That this is a sizable operation is evidenced by the fact that our department is equipped with 22 mechanical presses, ranging in capacity from 100 to 1500 tons. In addition, we have two fully automatic coating machines for lubricating workpieces, and seven continuous annealing furnaces. Our facility could easily handle 300,000 extruded blanks per month requiring over 1500 tons of steel as hot rolled bar stock.

Parts which are ideal for production by cold extrusion come within the following ranges: weight 2 to 15 lb.; diameter 1 to 6 in. O.D. and up to 4 in. I.D.; and length up to 20 in. These are general limits; in individual instances, parts both smaller and larger can be made.

Basic Considerations

Our experience has been that the best time to consider going to cold extrusion is when a part is in the preliminary design stage. Here the economic and functional advantages of producing extrusions in place of parts made from forgings, castings, tubing or machined from solid bar stock can be fully considered. Various factors may be discussed, such as whether to use an inexpensive sheet metal fabrication with extruded inserts in place of a heavy forging or casting. Other salient features of cold extrusion are:

- In short lengths, the process competes favorably with thick-walled seamless tubing, gives closer tolerances, better concentricity and a smoother finish with added diametrical steps where desired.
- Cold extruded parts finished on a hot upsetter offer many possibilities.
- A cold extruded automotive propeller shaft, complete with splines, can be produced, eliminating all machining operations.

In a number of instances, cold extrusion has emerged as the most economical way to make a standard part. A case in point is the control arm bushing (Fig. 1) for the suspension that houses the hexagonal torsion bar – a design currently being adopted by several automobile and truck makers. Cold extrusion saved 25% here. Originally, the part was a heat treated screw machine product made from 1035 steel.

From the designer's standpoint, advantages of cold extrusion are: (*a*) substitution of low-carbon or alloy steels for premium materials; (*b*) dimensional uniformity with close diametrical tolerances; (*c*) smooth finishes in the range of 10 to 50 micro-in.; (*d*) high mechanical properties by cold work alone; (*e*) parts made with zero draft angles and sharp corner radii; (*f*) elimination or substantial reduction of finishing operations such as machining, heat treating, grinding.

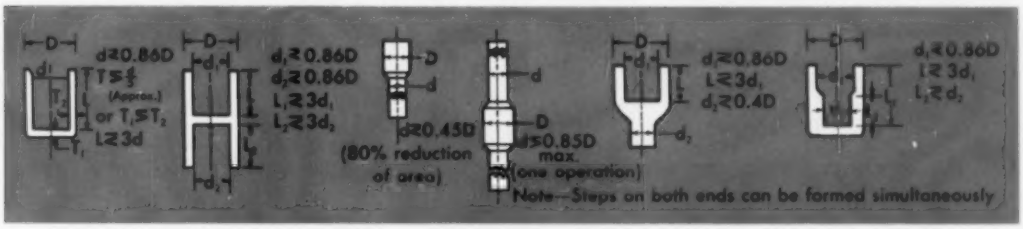
From the fabricator's standpoint, the advantages are: (*a*) material savings with excellent metal recovery; (*b*) reduction of the number of operations; (*c*) more parts per square foot of floor space; (*d*) fewer quality control problems.

Fig. 1 – By Cold Extruding This Bushing Housing for a Torsion Bar Suspension System, 1017 Carbon Steel Replaced a Heat Treated Screw Machine Part Made From 1035 Steel With a 25% Saving

*Development Engineer, Cold Extrusion Dept., Heintz Div., Kelsey-Hayes Co., Philadelphia.

Good *Poor* *Good* *Fair* *Poor* *Good* *Poor*

Internal diameters of different dimensions should be blended with angles or with as large a radius as possible. *Shoulders may be located anywhere but preferably should be at one end.* *Inside and outside steps should progress in size in same direction wherever possible.*



Cup — backward extruded *Double cup — backward extruded* *Solid — forward extruded* *Double end solid — forward extruded* *Cup — backward extruded with outside steps* *Cup — backward extruded with inside steps*

Fig. 2 — Design Parameters and Recommended Shapes for Cold Extruded Parts

However, it is generally the saving in material which is most significant and provides the greatest competitive advantage over other methods.

In designing a part for extrusion the following approaches are essential:

1. Define the function of the part and its relationship to adjacent parts; specify the mechanical properties needed, such as strength, toughness and wear resistance. It is often possible to combine several mating parts into one extrusion, thus eliminating an assembly. It is more practical for the designer to think in terms of physical requirements rather than of a specific steel analysis. Economies can result from substituting less expensive steels. Table I on p. 125 illustrates improvements in mechanical properties as a result of cold extrusion.

2. Next, consider the shape required. Cold extruded parts are generally cylindrical, but may be square or conical, hollow or solid, with varying wall thicknesses, webs, flanges, interior or exterior squares, octagons, hexagons, bosses, with splines or gear teeth on the exterior or interior, or both. The size of the piece is limited only by the available equipment. Figure 2 shows design parameters and recommended shapes.

3. Determine the quantity of parts required. Cold extrusion is a high-production operation employing long-life tools on fast presses. The capital investment in equipment and standard

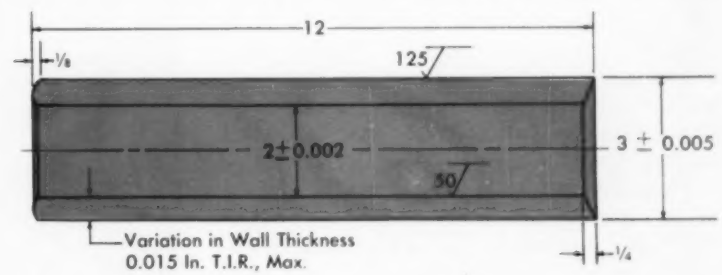


Fig. 3 — Basic Tubular Extrusion With Typical Dimensions

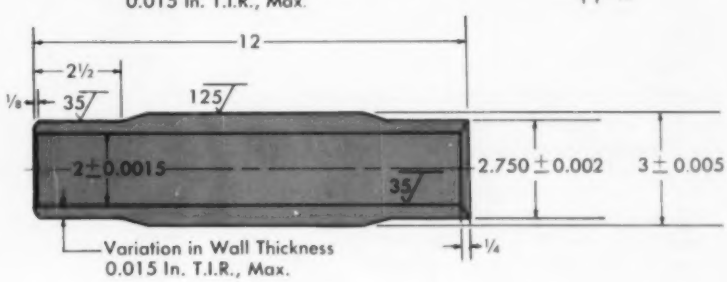


Fig. 4 — Refinement of Extrusion of Fig. 3 Gives Closer Tolerances and a Better Finish

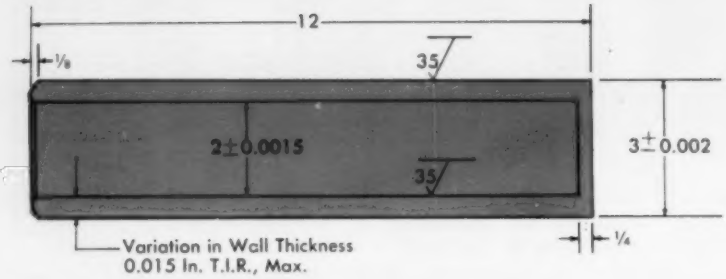


Fig. 5 – Further Refinement Gives Tolerances of 0.002 In. on O.D. With Improved Finish

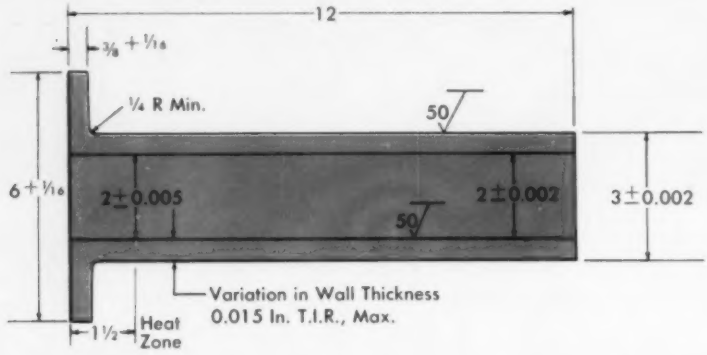


Fig. 6 – Hot Upsetting of Cold Extruded Part Gives Wide Flange. Method can also be used on solid parts

dies is relatively high. Production runs of 50,000 to 2,000,000 pieces per year are common. However, on some designs the high savings may permit a relatively short run.

4. Requirements on tolerances and finish should be considered. Parts cold extruded have tolerances equal to those in conventional turning and boring operations. The tolerance range on diameters, depending on size, may be 0.003 to 0.010 in. in quantity production. Concentricity, measured as a function of variation in wall thickness on tubular parts, can be held to within 0.015 in. T.I.R. (total indicator reading). Eccentricity between two or more external diameters can be held within 0.010 in. T.I.R. The same applies for internal diameters. Smooth shiny finishes are characteristic of cold extruded parts, and are inherent in the process. The usual surface finish range is about 35 micro-in. Often this may eliminate the need for grinding and honing.

These four points should be considered only as an initial guide. It should be remembered that tool development and other phases of the cold extrusion technique are advancing at a rapid pace.

Thick-walled seamless tubing is being used for such items as track link bushings for crawler tractors and diesel piston pins. In a number of applications, an extrusion has been found to be cheaper. In some instances the part is press finished on the O.D. and I.D. and requires only facing the ends.

Figure 3 shows the basic extrusion. The dimensions indicated are typical and ideal ones with which to work, but in individual instances they may vary considerably. This part is formed at full extrusion load, accounting for the wider

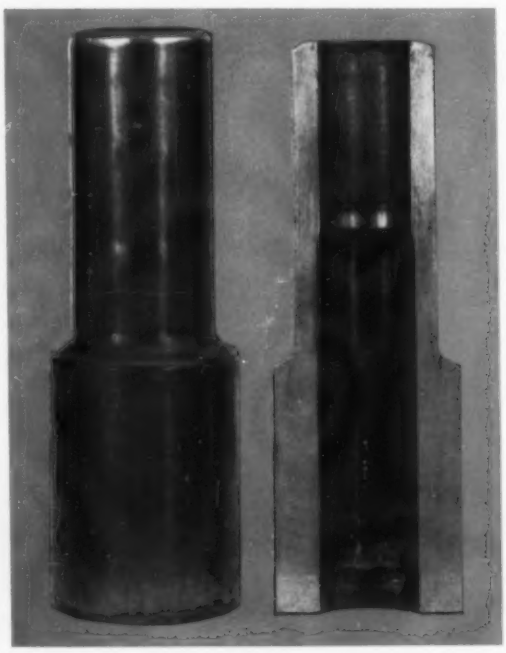


Fig. 7 – Transmission Reverse Sun Gear Blank Extruded From 4027 Steel With 10% Savings in Material. A costly bore drilling operation was eliminated

Table I – Mechanical Properties of Steels Before and After Cold Extrusion

	Before Extrusion (Annealed)			After Extrusion			
Type	Ultimate Strength	Yield Strength	Elongation in 2 In.	Ultimate Strength	Yield Strength	Elongation in 2 In.	Reduction in Area
1010	51,000 psi.	24,000	40%	118,500	117,400	13.5%	54.3%
1018	60,100	28,850	39	146,000	133,500	12.0	31.1
1030*	67,250	49,500	31	166,000	161,000	9.0	32.4
1035*	84,000	50,000	30	164,000	160,500	5.5	19.4
4130	81,250	52,250	28	166,500	139,000	14.5	47.3
4140	95,000	60,400	26	178,500	159,000	12.0	43.4
5130	89,000	55,000	28	153,000	148,000	12.0	40
8620	77,750	55,875	31	164,000	158,000	14.0	40.2
8630	81,750	54,000	29	171,000	166,350	12.0	46.4
8730	98,000	65,000	25	154,000	145,000	17.5	51.5
9115*	70,000	50,000	35	167,000	163,500	9.0	18.3

*As-received hot rolled bar.

tolerance of ±0.005 in. on the O.D. Concentricity, measured by supporting the piece on V-blocks on each end, total runout at any point inside or out, does not exceed 0.007 in. T.I.R. The variation in wall thickness is within 0.015 in. T.I.R. The finish in the bore is better than 50 micro-in. and on the O.D. is better than 125 micro-in.

Figure 4 shows a refinement of the basic extrusion shown in Fig. 3, reworking the ends of the O.D. and the bore. This part is similar to the basic extrusion in concentricity and runout, with closer tolerances and a finish on the inside and outside of 35 micro-in. Figure 5 is another refinement of the basic extrusion shown in Fig. 3, showing a straight tube with close O.D. and I.D. tolerances with a mirror finish throughout. In both Fig. 4 and Fig. 5, the tolerance of ±0.002 in. on the O.D. is actually used up in out-of-roundness and parts are suitable for press fitting even after a full carburizing cycle. In either instance, additional shapes on the O.D. or I.D. can be added for little or no cost.

The part shown in Fig. 6 is a new approach – hot upsetting a wide flange on a cold extruded part, whether it be tubular (as shown) or solid. Low-carbon or alloy steel bars above 1½ in. diameter have little or no upsetting qualities. All parts calling for a wide flange had to be hot forged and upset, or made from tubing and hot upset. The cold extrusion approach has been to combine the advantages inherent in both hot and cold work. By the use of induction heat for upsetting the flange, there is hardly any effect on the tolerance and finish of the cold extruded body.

Overcoming the Producibility Barrier...

*Contour Rolling**

As a hot forming process, contour rolling combines advantages of conventional rolling and extruding to produce varied configurations over relatively large areas. Parts made by this method exhibit desirable grain flow characteristics and material distribution advantages; machining operations are minimized or eliminated. The process can produce parts having relatively large areas when the dimensional characteristics may prohibit use of conventional impact or pressure-type forging machines.

Configurations may be uniform (symmetrical

*Based in large part on "Production Design Handbook", developed by the Materials and Equipment Div., Air Research and Development Command, U.S.A.F.

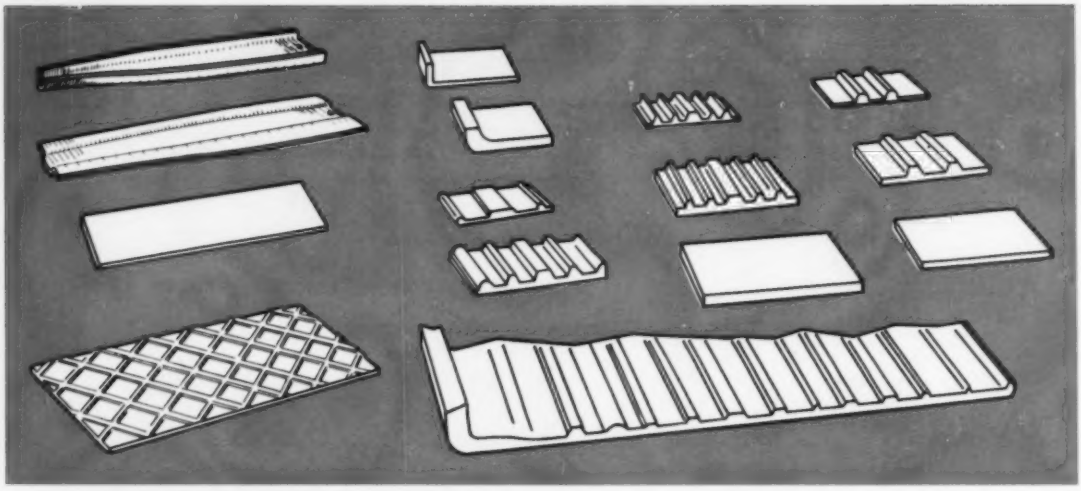


Fig. 1 – Typical Hot Rolled Sections

about a centerline) such as longitudinal ribs or panels, transverse ribs or panels and isogon patterns which utilize waffle-like stiffening. Configurations also may be nonuniform – completely unsymmetrical with ribs, panels, and bases placed according to stress and the attaching requirements of the part. A variety of designs in hot rolled sections is depicted in Fig. 1. The automobile door hinge shown in Fig. 2 is produced from a steel section hot rolled to shape. Special sections such as this can reduce or eliminate other production operations such as machining, grinding or welding. Often less steel is needed and scrap losses can be cut.

In cold roll forming, a flat strip of metal is progressively shaped into the configuration de-

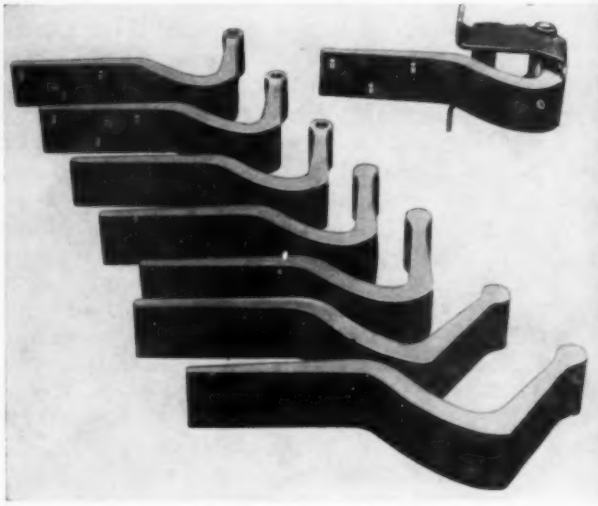


Fig. 2 – Auto Door Hinge, Shown in Upper Right, Was Made From a Special Hot Rolled Steel Section. Starting at bottom, formed pieces show sequence of operations the fabricator used to make the finished product. (Courtesy U. S. Steel Corp.)

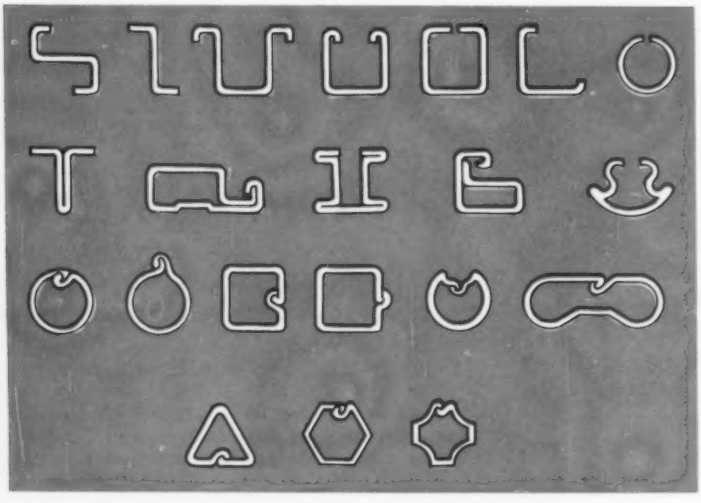


Fig. 3 – Typical Shapes Which Can Be Produced by Cold Roll Forming

sired by passing it through a series of rolls. A wide variety of shapes can be produced to close tolerances. Cold rolled steel is most commonly used for roll formed parts. It gives a limited amount of spring back and can be rolled without a lubricant. Hot rolled steel can also be formed but liberal quantities of lubricant must be used to flush away scale. Aluminum, copper, brass, bronze and zinc sheets are roll formed as are many precoated metals. In the latter instance, the bend radius must be kept large enough to avoid cracking of the coating at the bends. Figure 3 illustrates design possibilities with cold rolled sections.

Stainless steels of austenitic and ferritic types are roll formed where the need for elaborate shapes or continuous lengths justifies the tooling cost. Since stainless work hardens during forming, about twice the forming capacity is required compared to steel.

Three types of curved sections can be produced by roll forming: (*a*) straight sections or parts with parallel bend lines; (*b*) straight flanged parts, or parts consisting of large flat portions or webs and nonparallel bend lines; (*c*) smoothly contoured parts, or parts with large radii and only minor flat portions or webs. The variety of shapes that can be made by roll forming includes channels, angles, "Z's", piping and tubing. Sections can be notched, pierced, coiled, printed or embossed with only little additional cost. Many structural parts are being produced by roll forming to take advantage of a high strength-to-weight ratio, good surface finish, and close tolerances.

Titanium and magnesium alloys do not have the ductility required for roll forming at room temperature. They can be heated to a temperature suitable for forming, by induction coils placed between the rolls.

Overcoming the Producibility Barrier . . .

*Impact Extrusion**

ENGINEERS ARE NOW utilizing impacts with configurations which have advanced far beyond conventional can or tube-type parts. Designs formerly made by drawing, machining, stamping, casting, or forging are being impact extruded more economically, with better mechanical properties and appearance. Impact parts considered impossible to make just a year or two ago are now routine production.

Although the accent is still on aluminum – with lots of activity in the stronger, heat treatable alloys – impact extruders have progressed from soft alloys to hard alloys and to other metals, such as brass, steel, titanium and zirconium. In aluminum impact extrusions, the mechanical properties exceed those obtained by forging plus the added advantage gained by cold working. Since the grain flow lines of an impact follow the contour of the finished shape, impacts are stronger than drawn or cast part or parts machined from rod and bar. Harvey can produce aluminum impacts with an ultimate tensile strength of 92,000 to 97,000 psi. The surface of impacts is exceptionally smooth, requiring no polishing or buffing in the natural condition. Surface finish of 125 rms. is standard; however, surfaces of 20 rms. can be obtained.

The following features are common to most parts produced by the impact method: zero-degree draft, close tolerances, and approximate symmetry. Although many of the shapes being produced are round, oval, square, or rectangular, so long as the design is fairly symmetrical, polygonal configurations do not cause trouble.

Intricate shapes can be made with proper die design. By using a hollow punch, a tube within a tube can be produced. Pads, flutings, lugs, ribs, tapers, serrations, and splines are other design devices being incorporated into an impacted part. Advances have been made in complex shapes with a variable change in wall thickness. Bimetal impacts, impacts having a vertical and lateral metal flow, and clad impacts are new developments which intrigue the engineer. Furthermore, multiple parts can be produced as one unit, eliminating joint assemblies.

*Prepared by Technical Department, Impact Div., Harvey Aluminum, Inc., Torrance, Calif.

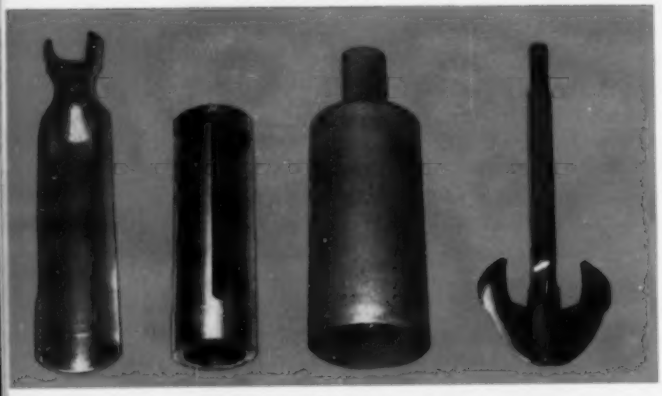


Fig. 1 – High-Strength Aluminum Impact Extrusions. Left to right – body housing for pressure unit with ultimate tensile strength of 92,000 to 97,000 psi.; finned component for rocket motor produced with integral slots for blade assembly; bottle or pressure container; poppet valve

Closer tolerance is another reason why impacts are being used for more products. Under normal circumstances, dimensional tolerances can be held within ±0.005 to ±0.015 in. These tolerances are lower for certain configurations. Size of impacts depends upon available equipment and the reduction in area required to produce the desired configuration. Harvey Aluminum has produced impacts 14 in. in diameter.

Impacts for Many Applications

In the automotive industry, speedometer drums and ornamental parts, formerly produced by casting or machining, are now being made as an aluminum impact extrusion. Oil filter shells used to be made by drawing; now they're impacted at a much faster rate. In appliances, refrigerator headers, once machined, are now impacted. In electronics, condenser cans, heat dissipators, tube shields, and connection covers are made as impacts instead of by drawing.

Aircraft applications for aluminum impacts include landing gear pistons, propeller hubs, and fluid line couplings. All were previously made by machining. Structural support sections used to be forged; now they're being made as impact extrusions at less cost.

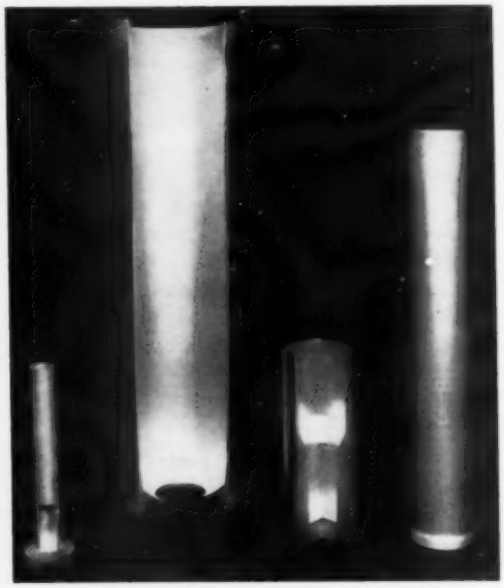
Ordnance items once machined – fuse sleeves, shell casings, flare tubes – are now impact extruded. In the atomic energy field, fuel containers and fuel container plugs used to be made as a two-stage drawing operation; now they're impacted. Miscellaneous parts, such as air and hydraulic cylinders, business machine platen cores, motor housings and rifle scopes, are now impacted instead of machined or die cast.

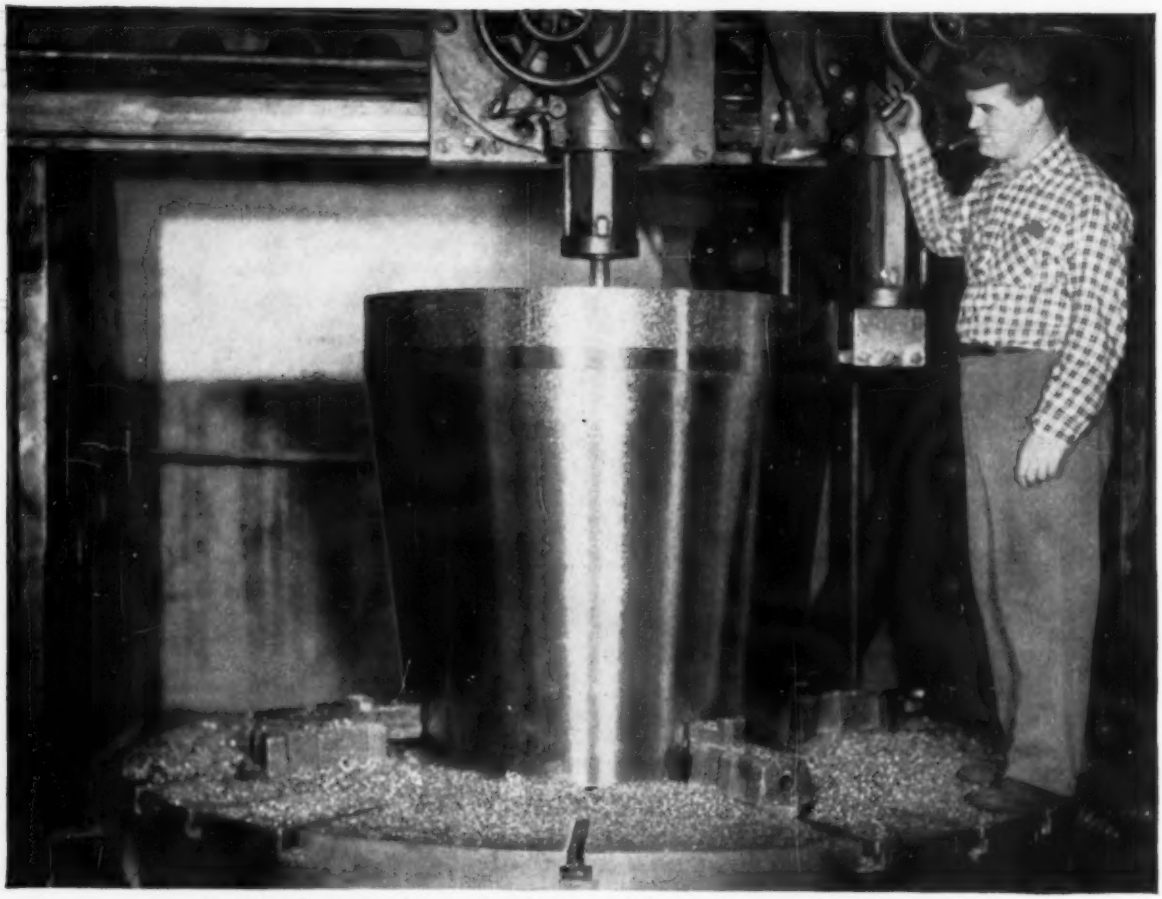
Specific Examples

In Fig. 1, the body housing (far left) is produced as an impact from a slug 2.105 in. diameter and 5.332 in. long, weighing 1.86 lb. To machine this part from bar stock, the material required would be 2⅛ in. diameter and 8¾ in. long, weighing 3.2 lb. Made as an impact, the material saving alone is 100%.

Also in Fig. 1, the poppet valve (far right) is made as an impact from a slug 3⅛ in. diameter and 2 5/6 in. long, weighing 1.82 lb. Compare this to the same part machined from bar stock 3⅛ in. diameter and 10 in. long, weighing 7.89 lb. Material saving here is 300%. Although these parts are not finished in every detail during impacting, the secondary operations of threading, turning, and so forth, applicable to both parts, are 70% less than required to produce the parts from solid stock. In wrought aluminum alloys, the mechanical properties were increased 20% by impacting.

Fig. 2 – These Tube-Type Aluminum Impacts Would Not Be Practical by Other Manufacturing Methods. Left to right – blank for a gear or sprocket head tubular shaft; high-pressure cylinder with integral spherical bulkhead and increased metal thickness on open end; basic impact to save material in large machined part; closed tube with thread attachment shoulder





Five times longer service expected from Ni-Vee bronze filter cone. Cast by A. W. Cadman Mfg. Co., Pittsburgh, Pa. Finished and installed in 12" automatic self-cleaning strainer by S. P. Kinney Engineers, Carnegie, Pa.

Cone made of Ni-Vee* bronze to last 5 times longer in acid river water

The filter cone you see above is being readied for work in corrosive Monongahela River water.

That's why it's made of Ni-Vee bronze.

Expected life is at least five times longer than its predecessor, a grey iron cone now badly eaten away. Installed in a 12" automatic self-cleaning strainer, the Ni-Vee bronze cone will give long-lasting support to filter elements that remove solids from water used for blast furnace cooling.

Another important consideration in making this cone was machinability – all outer surfaces were drilled to receive filtering elements. Ni-Vee bronze easily met this need.

Versatile Ni-Vee bronze

Ni-Vee bronze does a multitude of industrial jobs. Five basic bronze compositions are available – Ni-Vee A, B, C, D, and E. They're modifiable to meet all industrial needs for brass and bronze constructional, pressure or bearing castings.

All the Ni-Vee bronzes deliver excellent "as cast" strength, improvable with heat treatment. (For example, Ni-Vee A bronze yield strength can be increased from 22,000 psi as cast, to 55,000 psi!) In addition, they supply easy castability, low shrinkage, pressure tightness, fine grain size and overall economy.

Each Ni-Vee bronze provides special properties. Type A gives extreme strength. Type D furnishes very high resistance to seizure and galling. All types show little dezincification or stress corrosion under corrosive attack.

Informative booklet on Ni-Vee bronzes

"Engineering Properties and Applications of Ni-Vee Bronzes" covers alloy compositions, strength properties, resistance to high temperatures, corrosion, wear, along with other helpful information. Write us for your copy.

*Registered trademark

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N. Y.

NI-VEE BRONZES

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Standard Commercial Wrought Copper and Copper-Base Alloys

Source: Copper & Brass Research Association

Alloys listed are those which have been most commonly used in large quantities over the years. In addition there are many special and proprietary alloys such as aluminum bronzes, cadmium bronzes, beryllium coppers, aluminum-tin bronzes, aluminum-silicon bronzes, silicon bronzes, copper-chromium, copper zirconium and other combinations for special applications.

Names	Nominal Composition	Forms Most Commonly Ordered Indicated by Nearest Applicable A.S.T.M. Specification						Mechanical Property Range (Hardest to Softest Commercial Forms)			Fabricating Characteristics and Typical Uses
		Flat Products	Drawn Rods and Flats	Shapes	Wire (Except Flat)	Tube	Pipe	Tensile Strength 1000 Psi.	Yield (0.5% Offset) 1000 Psi.	Elongation, % in 2 In.	
Coppers											
Electrolytic tough pitch copper (ETP)	Cu 99.90 min. O 0.04	B 48 B 124, No. 12 B 133 B 152 B 187 B 272	B 49 B 124, No. 12 B 133 B 187	B 124, No. 12 B 133 B 187	B 1, B 2, B 3 B 33, B 47 B 49, B 189 B 116, B 298	B 111, B 188	B 188	66-32	53-10	55-4	Excellent hot and cold workability; good forgeability; fabricated by coining, coppersmithing, drawing and upsetting, hot forging and pressing, spinning, swaging, stamping. *Uses:* downspouts, gutters, roofing, gaskets, auto radiators, busbars, wire.
Phosphorus-deoxidized copper, high residual copper (DHP)	Cu 99.90 min. P 0.02	B 124, No. 12 B 133 B 152-DHP	B 12 B 124, No. 12 B 133	B 124, No. 12 B 133	—	B 13 B 68-DHP B 75-DHP B 88, B 111 B 280, B 306	B 42 B 302	55-32	50-10	45-8	Similar properties and fabricated as above. *Uses:* gas and heater lines; oil burner tubes; plumbing pipe and tube, condenser tube, evaporator and heat exchanger tubes; dairy and distiller tubes; steam and water lines; air, gasoline and hydraulic lines.
Oxygen-free copper (OF)	Cu 99.92 min.	B 48 B 124, No. 12 B 133, B 152 (OF) B 187 (OF), B 272	B 12 (OF) B 49 B 124, No. 12 B 133, B 187 (OF)	B 124, No. 12 B 133 B 187 (OF)	B 1, B 2, B 3 B 33, B 189 B 298	B 13 (OF) B 68 (OF) B 75 (OF) B 188 (OF) B 280	B 42 B 188 (OF)	66-32	53-10	55-4	Fabricating characteristics same as tough pitch copper. Excellent conductivity. *Uses:* busbars, waveguides.
Brasses, Nonleaded											
Gilding, 95%	Cu 95 Zn 5	B 36, No. 1 B 134, No. 1	—	—	B 134, No. 1	—	—	64-34	58-10	45-4	Excellent cold workability, good hot workability for blanking, coining, drawing, piercing and punching, shearing, spinning, squeezing and swaging, stamping. *Uses:* coins, medals, bullet jackets, fuse caps, primers, plaques, jewelry, base for gold plate.
Commercial bronze, 90%	Cu 90 Zn 10	B 36, No. 2 B 130 B 134, No. 2	—	B 131	B 134, No. 2	*	—	90-37	62-10	50-3	Generally fabricated by same methods as gilding, 95%, plus heading and upsetting, roll threading and knurling, hot forging and pressing. *Uses:* etching bronze, grillwork, screen cloth, weatherstripping, lipstick cases, compacts, marine hardware, rivets, screws.
Jewelry bronze, 87.5%	Cu 87.5 Zn 12.5	*	—	—	*	—	—	97-39	62-11	46-3	Fabricating characteristics same as gilding, 95%. Slightly better machinability. Fabricated by same processes plus heading and upsetting, roll threading and knurling. *Uses:* angles, channels, chain, fasteners, costume jewelry, lipstick cases, compacts, base for gold plate.
Red brass, 85%	Cu 85 Zn 15	B 36, No. 3 B 134, No. 3	—	—	B 134, No. 3	B 111 B 135, No. 1	B 43	105-39	63-10	55-3	Fabricating characteristics and processing same as jewelry bronze, 87.5%. *Uses:* Weatherstrip, conduit, sockets, fasteners, fire extinguishers, condenser and heat exchanger tubes, plumbing pipe, radiator cores.
Low brass, 80%	Cu 80 Zn 20	B 36, No. 4 B 134, No. 4	—	—	B 134, No. 4	—	—	125-42	65-12	55-3	Excellent cold workability. Fabricated by same processes as gilding, 95%, plus heading and upsetting, roll threading and knurling. *Uses:* battery caps, bellows, musical instruments, clock dials, pump lines, flexible hose.
Cartridge brass, 70%	Cu 70 Zn 30	B 19 B 36, No. 6 B 134, No. 6	—	—	B 134, No. 6	B 135, No. 2	—	130-44	65-11	66-3	Cold working characteristics excellent. Same fabrication processes as low brass, 80%, except for coining, roll threading and knurling. *Uses:* radiator cores and tanks, flashlight shells, lamp fixtures, fasteners, locks, hinges, ammunition components, plumbing accessories, pins, rivets, screws, springs.

*Forms commonly ordered for which there are no appropriate A.S.T.M. specifications.

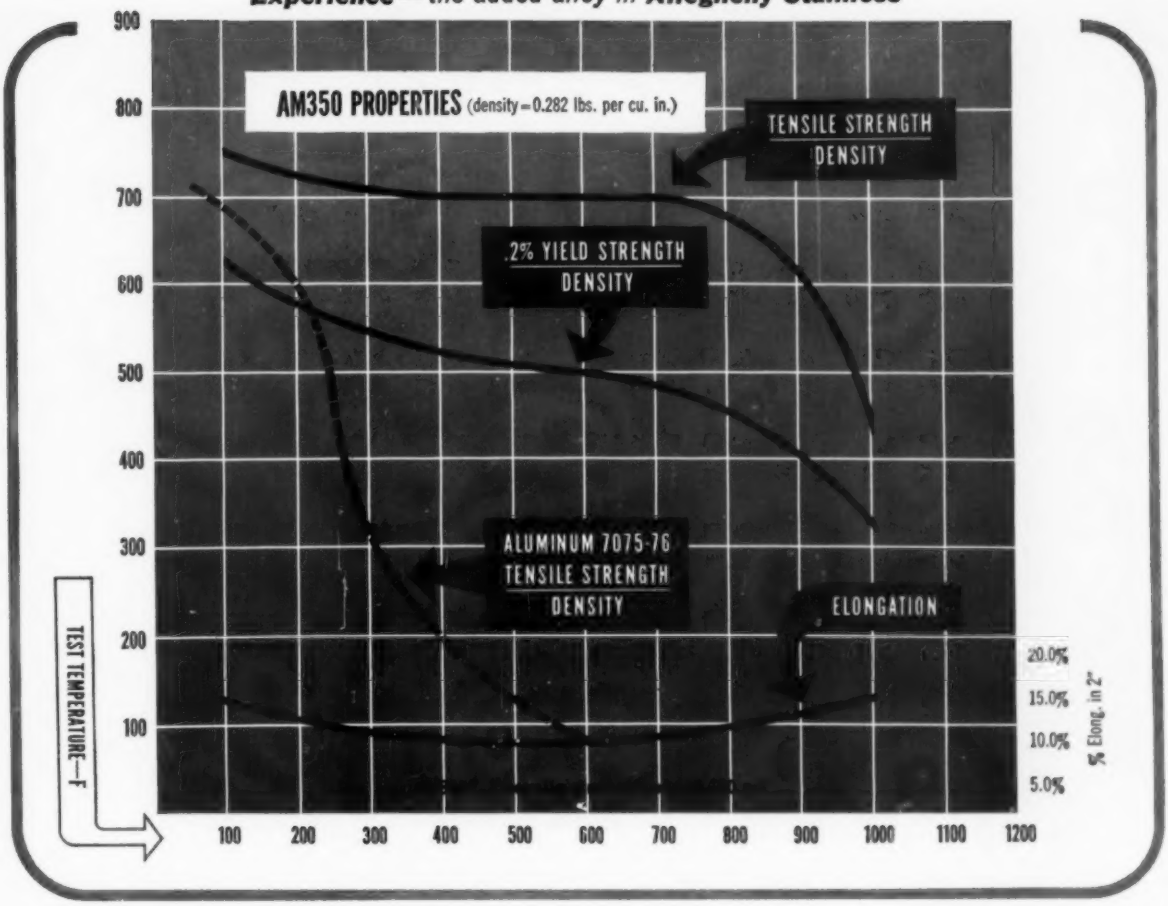
(Table continued overleaf)

Names	Nominal Composition	Forms Most Commonly Ordered Indicated by Nearest Applicable A.S.T.M. Specification						Mechanical Property Range (Hardest to Softest Commercial Forms)			Fabricating Characteristics and Typical Uses
		Flat Products	Drawn Rods and Flats	Shapes	Wire (Except Flat)	Tube	Pipe	Tensile Strength 1000 Psi.	Yield (0.5% Offset) 1000 Psi.	Elongation, % in 2 In.	
Yellow brass	Cu 65 Zn 35	B 36, No. 8 B 134, No. 7	*	—	B 134, No. 7	—	—	128-46	62-14	65-3	Excellent cold working characteristics. Same fabrication processes as low brass, 80%. *Uses:* same as cartridge brass except not used for ammunition.
Muntz metal	Cu 60 Zn 40	*	*	—	—	B 111 B 135, No. 5	—	74-52	55-20	52-10	Excellent hot forming and forgeability characteristics for blanking, forming and bending, hot forging and pressing, hot heading and upsetting, shearing. Best machinability of the nonleaded brasses. *Uses:* large sheets for architectural use, large nuts and bolts, brazing rod, condenser plates, condensers, evaporator and heat exchanger tube, hot forgings.
Leaded Brasses											
Leaded commercial bronze	Cu 89 Pb 1.75 Zn 9.25	B 140-B	B 140-B	B 140-B	—	—	—	60-37	55-12	45-10	Excellent machinability. *Uses:* screws, screw machine parts, pickling crates.
Low-leaded brass (tube)	Cu 66 Pb 0.5 Zn 33.5	—	—	—	—	B 135, No. 3	—	75-47	60-15	60-7	Combines good machinability and excellent cold working characteristics. Fabricated by forming and bending, machining, piercing and punching. *Uses:* pump and power cylinders and liners, ammunition primers, plumbing accessories.
Low-leaded brass	Cu 65 Pb 0.5 Zn 34.5	B 121, No. 2	—	—	—	—	—	74-46	60-14	65-8	Similar to low-leaded brass (tube). Commonly fabricated by blanking, drawing, machining, piercing and punching, stamping. *Uses:* butts, hinges, watch backs.
Medium-leaded brass	Cu 65 Pb 1 Zn 34	B 121, No. 3	*	*	*	—	—	58-47	60-15	60-7	Similar to low-leaded brass with slightly better machinability. Blanking, heading and upsetting, machining, piercing and punching, roll threading and knurling, stamping. *Uses:* butts, gears, nuts, rivets, screws, dials, engravings, instrument plates.
High-leaded brass (tube)	Cu 66 Pb 1.6 Zn 32.4	—	—	—	—	B 135, No. 4	—	73-53	60-20	50-7	Better machinability than leaded brasses listed above. Fabricated by piercing, punching and machining. *Uses:* general-purpose screw-machine products.
High-leaded brass	Cu 65 Pb 2 Zn 33	B 121, No. 5	*	—	—	—	—	85-49	62-17	52-5	Similar to high-leaded brass (tube) with slightly better machinability. Same fabrication processes as medium-leaded brass. *Uses:* clock plates and nuts, clock and watch backs, gears, wheels, channel plate.
Extra-high-leaded brass	Cu 63 Pb 2.5 Zn 34.5	B 121, No. 6	—	—	—	—	—	74-49	60-17	50-7	Excellent machinability. Usually fabricated by same processes as high-leaded brass. *Uses:* same as high-leaded brass.
Free-cutting brass	Cu 61.5 Pb 3.0 Zn 35.5	B 16	B 16	B 16	—	—	—	68-40	52-18	53-18	Excellent machinability. Commonly roll threaded and knurled, machined. *Uses:* gears, pinions; automatic high-speed screw machines.
Leaded muntz metal	Cu 60 Pb 0.6 Zn 39.4	B 171	—	—	—	—	—	54 (as hot rolled)	20	45	Combines good machinability with excellent hot forming characteristics. *Uses:* condenser tube plates.
Free-cutting muntz metal	Cu 60 Pb 1 Zn 39	—	—	—	—	B 135, No. 6	—	80-54	60-20	40-5	Similar to leaded muntz metal in fabricating characteristics. *Uses:* automatic screw machine products.
Forging brass	Cu 59 Pb 2 Zn 39	B 124, No. 2	B 124, No. 2	B 124, No. 2	—	—	—	82 (as extruded)	30	45	Excellent hot forming and machining characteristics. Fabricated by hot forging, heading, upsetting, pressing and machining. *Uses:* forgings and pressings of all kinds.
Architectural bronze	Cu 57 Pb 3 Zn 40	—	*	*	—	—	—	80 (as extruded)	30	30	Excellent machinability and hot forming characteristics. Fabricating by hot forging and pressing, forming, bending and machining are common. *Uses:* architectural extrusions, trim, butts, hinges, lock bodies, forgings.
Tin and Aluminum Brasses											
Inhibited admiralty	Cu 71 Sn 1 Zn 28	B 171	—	—	*	B 111-A, B, C, D	—	55-48	22-18	65-60	Excellent cold working characteristics for forming and bending. *Uses:* condenser, evaporator and heat exchanger tubes, condenser tube plates, distiller tubes, ferrules.
Naval brass	Cu 60 Sn 0.75 Zn 39.25	B 21-A B 124, No. 3 B 171	B 21-A B 124, No. 3	B 21-A B 124, No. 3	*	*	—	88-55	66-25	50-17	Excellent hot working and hot forging characteristics. Fabricated by blanking, drawing, bending, heading and upsetting, hot forging, pressing. *Uses:* aircraft turnbuckle barrels, bails, bolts, marine hardware, nuts, propeller shafts, rivets, valve stems, condenser plates, welding rod.
Leaded naval brass	Cu 60 Sn 0.75 Pb 1.75	B 21-C	B 21-C	B 21-C	—	—	—	75-57	53-26	40-15	Combines excellent hot forging and machining

Leaded naval brass	Cu 60 Sn 0.75 Pb 1.75 Zn 37.5	B 21-C	B 21-C	B 21-C	—	—	—	75-57	53-25	40-15	Combines excellent hot forging and machining characteristics. Fabricated by hot forging and pressing, machining. *Uses:* marine hardware, screw machine products, valve stems.
Manganese bronze (A)	Cu 58.5 Sn 1.0 Fe 1.4 Mn 0.1 Zn 39.0	B 138-A	B 124, No. 4 B 138-A	B 124, No. 4 B 138-A	—	—	—	84-65	60-30	33-19	Hot forming and forging characteristics similar to naval brass. Fabricated by hot forging, hot heading and upsetting. *Uses:* clutch disks, pump rods, shafting, balls, valve stems and bodies.
Aluminum brass	Cu 76 Al 2 Zn 22	—	—	—	—	B 111-B, D	—	69	27	55	Excellent cold workability for forming and bending. *Uses:* same as inhibited admiralty.
Phosphor Bronzes											
(Tin Bronzes)											
Phosphor bronze 5% (A)	Cu 95 Sn 5	B 100, No. 1 B 103-A B 139-A	B 139-A	B 139-A	B 159-A	•	—	140-47	80-19	64-2	Excellent cold workability. Fabricated by blanking, drawing, bending, heading and upsetting, roll threading and knurling, shearing, stamping. *Uses:* bellows, Bourdon tubing, clutch disks, cotter pins, diaphragms, fasteners, lock washers, wire brushes, chemical hardware, textile machinery, welding rod.
Phosphor bronze 8% (C)	Cu 92 Sn 8	B 103-C B 139-C	B 139-C	B 139-C	B 159-C	—	—	140-55	80-24	70-2	Good cold workability for blanking, drawing, forming and bending, shearing, stamping. Generally used for more severe service conditions than phosphor bronze 5% (A).
Phosphor bronze 10% (D)	Cu 90 Sn 10	B 103-D B 139-D	B 139-D	B 139-D	B 159-D	—	—	147-68	38-	70-3	Good cold workability for blanking, forming and bending, shearing. *Uses:* heavy bars and plates for severe compression, good wear and corrosion resistance, bridge and expansion plates and fittings, articles requiring good spring qualities, resiliency, fatigue resistance.
Phosphor bronze 1.25% (E)	Cu 98.75 Sn 1.25	•	—	—	B 105	—	—	79-40	80-14	68-4	Excellent cold working characteristics, good hot formability. Fabricated by blanking, bending, heading and upsetting, shearing, swaging. *Uses:* electrical contacts, flexible hose, pole-line hardware.
Free-cutting phosphor bronze	Cu 88 Pb 4 Zn 4 Sn 4	B 139-B2	B 139-B2	B 139-B2	—	—	—	75-44	63-19	50-15	Excellent machinability, good cold workability. Fabricated by blanking, drawing, bending, machining, shearing, stamping. *Uses:* Bearings, bushings, gears, pinions, shafts, thrust washers, valve parts.
Silicon Bronzes											
(Copper-silicon alloys)											
High-silicon bronze (A)	Cu 94.8 min. Si 3	B 96-A B 97-A B 98-A B 100, No. 2	B 98-A B 124, No. 7	B 98-A B 124, No. 7	B 99-A	B 315	B 315	145-56	70-21	70-3	Excellent hot and cold working characteristics, fair forgeability. Blanking, drawing, heading and upsetting, hot forging and pressing, roll threading and knurling, shearing and swaging. *Uses:* aircraft hydraulic pressure lines, marine hardware, bearing plates, cable, chemical equipment, propeller shafts.
Low-silicon bronze (B)	Cu 96.0 min. Si 1.5	B 97-B B 98-B	B 98-B	B 98-B	B 99-B B 105, No. 2.5	•	—	95-40	69-15	55-11	Similar to high-silicon bronze (A).
Cupronickel and Nickel Silvers											
Cupronickel 30%	Cu 70 Ni 30	B 122, No. 5 B 171	•	—	—	B 111	—	75-54	70-30	45-15	Good hot and cold workability. Fabricated by forming and bending, welding. *Uses:* condensers, condenser plates, distiller tubes, evaporator and heat exchanger tubes, ferrules, salt water piping.
Cupronickel 10%	Cu 88.7 Fe 1.3 Ni 10	B 171	—	—	—	B 111	—	60-44	57-16	42-10	Similar to cupronickel 30%.
Nickel silver, 65-18	Cu 65 Ni 18 Zn 17	B 122, No. 2 B 151-A B 206-A	B 151-A	—	B 206-A	—	—	103-56	90-25	45-3	Excellent cold working characteristics. Fabricated by blanking, drawing, etching, bending, heading and upsetting, roll threading and knurling, shearing, spinning, swaging. *Uses:* rivets, screws, table flatware, zippers, camera parts, base for silver plate, costume jewelry hollow ware.
Nickel silver, 55-18	Cu 55 Ni 18 Zn 27	B 122, No. 6 B 151-B B 206-B	B 151-B	—	B 206-B	—	—	145-60	90-27	60-2	Good cold workability for blanking, forming and bending, shearing. *Uses:* optical goods, springs, resistance wire.
Nickel silver 65-15	Cu 65 Ni 15 Zn 20	•	—	—	—	—	—	92-53	79-18	43-2	Excellent cold working characteristics. Fabricated by blanking, drawing, bending, heading and upsetting, roll threading and knurling, shearing, spinning, squeezing and swaging. *Uses:* camera parts, optical equipment, etching stock, jewelry
Nickel silver, 65-12	Cu 65 Ni 12 Zn 23	B 151-D B 206-D	B 151-D	—	B 206-D	—	—	93-52	79-18	48-2	Similar to nickel silver, 65-15, in characteristics, fabricating practices and uses.
Nickel silver, 65-10	Cu 65 Ni 10 Zn 25	B 122, No. 3 B 151-E	B 151-E	—	B 206-E	—	—	130-49	76-18	50-1	Similar to nickel silver, 65-15, in characteristics and fabricating processes. Same uses as 65-15.

*Forms commonly ordered for which there are no appropriate A.S.T.M. specifications.
†For 66,000 psi. tensile strength.

Experience *— the added alloy in* ***Allegheny Stainless***



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They are proving the answer to many space age problems. Airframe and other structural parts, pressure tanks, power plant components, high pressure ducting, etc. are all natural missile and supersonic aircraft applications for AM-350 and AM-355.

AVAILABILITY: AM-350, introduced several years ago, is available commercially in sheet, strip, foil, small bars and wire. AM-355, best suited for heavier sections, is available commercially in forgings, forging billets, plates, bars and wire.

CORROSION RESISTANCE: Compared to the more familiar stainless grades, AM-350 and AM-355 resist corrosion and oxidation better than the hardenable grades (chromium martensitic) and only slightly less than the 18 and 8's. They resist stress corrosion at much higher strength levels than do martensitic stainless grades.

SIMPLE HEAT TREATMENT: High strength is developed by two methods. Both minimize oxidation and distortion problems. The usual is the Allegheny Ludlum-developed sub-zero cooling and tempering (SCT): minus 100F for 3 hrs plus 3 hrs at 850F. Alternate method is Double Aged (DA): 2 hrs at 1375F plus 2 hrs at 850F.

EASY FABRICATION: AM-350 and AM-355 can be spun, drawn, formed, machined and welded using normal stainless procedures. In the hardened conditions, some forming may be done . . . 180 degree bend over a 3T radius pin. Also AM-350 can be dimpled in the SCT condition to insure accurate fit-up.

For further information, see your A-L sales engineer or write for the booklet "Engineering Properties, AM-350 and AM-355." ***Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa. Address Dept. MP22.***

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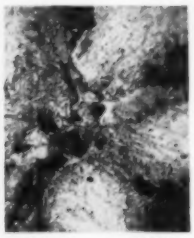

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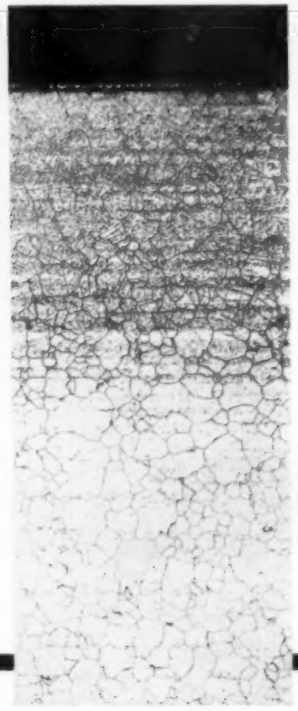

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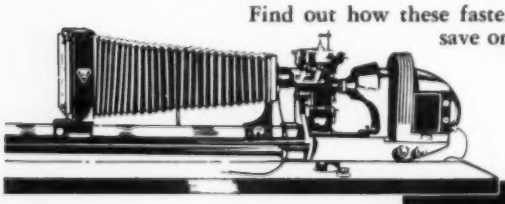

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*Copper-Base Alloys**

PRODUCIBILITY does not always require a new alloy, but often a new use for an old one. For example, an automobile maker encountered difficulties in making the escutcheon for the front bumper lamps on its latest models. Breakage of the part was high and the finish did not match the chromium-plated bumper. By changing to a copper alloy similar to cartridge brass, 70% (see Data Sheet, p. 128-B), he reduced breakage to less than 1% and obtained a plated surface which matched the finish of the bumper.

Radar Tube Problems

Reliability is a problem equally as important as producibility especially in radars which are used for aircraft detection and guidance. Dependable performance is essential. Raytheon Co., Waltham, Mass., is making a new type of electronic tube called the Amplitron, which boosts the output power of radar installations by 8 to 14 times and nearly doubles their range. Problems in tube design and manufacture include extreme mechanical accuracy, obtaining durable connections, heat dissipation and vacuum retention.

Although the anode cavity depends on maintaining tight dimensional tolerances for proper performance, it can be formed for some tube designs out of a solid blank of oxygen-free copper by cold forging—with a single press stroke. Copper's malleability makes this possible. The many connections can be brazed reliably because of good joining properties.

Heat could be a problem in the tube because of its high output (above 4 megawatts). Copper's thermal conductivity handles it. Good high-temperature characteristics of the metal are enhanced by its freedom from oxygen. Oxidation, scale formation and conductivity losses are eliminated. The high (50 to 70%) electrical efficiency of the tube depends, of course, on copper's electrical conductivity.

Vacuum retention in a tube is excellent because oxygen-free copper is not only nonporous but its high purity prevents the formation of gases. The vacuum envelope is therefore secure; nothing seeps in or is generated within it.

Boat Trailer Bushing

Steel has been replaced by 70-30 cartridge brass in bushings of boat trailers made by Holsclaw Bros., Inc., Evansville, Ind. Bushings are made from light drawn brass tubes, and range from 3/8 to 13/16 in. I.D. and 1½ to 14½ in. long. They are inserted in the rubber rollers that facilitate loading and unloading a boat to and from a trailer. A pneumatic press inserts and flares the bushings at each end to hold the roller in place. Brass tube takes the flaring operation without cracking. This excellent formability and inherent corrosion resistance have decreased rejects and improved the performance of the rollers. They always roll.

Water Pumps

The use of bronze has increased producibility and sales appeal of sump pump motors made by Franklin Electric Co., Inc., Bluffton, Ind. The company recently switched to bronze casings for its Series 350 Submatic motor (Fig. 1). Object: better corrosion resistance and appearance than the metal previously used.

Because it is always in contact with water, the pump is exposed to highly corrosive conditions. Its buoyant watertight bronze casing automati-

*Based on an article by the Copper and Brass Research Assoc.

Fig. 1 – Bronze Shielding for Sump Pump Motor Assures Protection Against Corrosion

cally actuates a motor switch as the sump water level changes, turning on the pump when the water rises and shutting it off as it falls. This arrangement eliminates unsightly and complicated external floats and switches.

Sprinkler Cost Cut

Excessive machining time slowed production of threaded brass rings for lawn sprinkler systems at H. L. Gee Mfg. Co., Beverly Hills, Calif. The rings, which are used in the moving piston parts of the company's Gee King pop-up sprinkler heads, were difficult to machine without excessive scrap accumulation. After changing to high-leaded brass tube, machining time dropped by one third and scrap was reduced by 80%.

Printed Circuits

The Taylor Fibre Co. of Norristown, Pa., saved 30 to 50% in assembly costs by using printed circuits (Fig. 2), constructed from a new copper-clad laminate (glass-epoxy), in infrared photo-reconnaissance equipment. This equipment is now in advanced pilot production at Haller, Raymond & Brown, Inc., State College, Pa. The printed circuit was adopted in 1958 when the

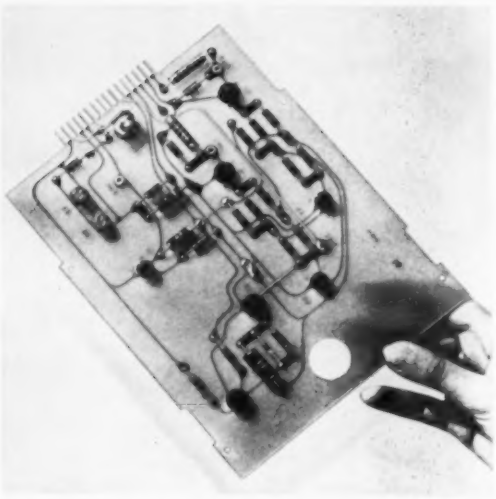
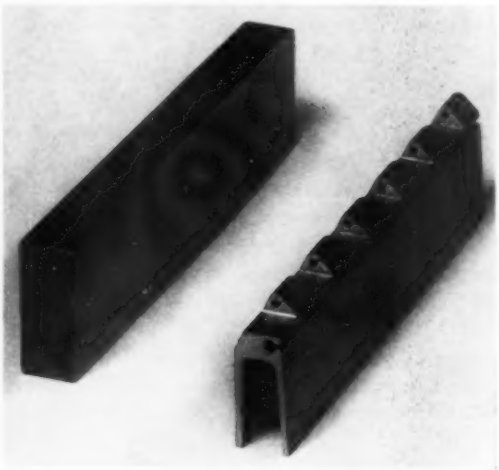


Fig. 2 – Printed Circuit Panel (a Copper-Clad Plastic Laminate), Used in Redesigned Airborne Camera, Requires Less Space and Can Be Easily Removed for Service

Fig. 3 – Change to Extruded Hinge Part Cut Costs 40%



firm redesigned the aerial camera from the ground up. Miniaturization and modular construction were prime targets.

Etched circuitry permits a reduction of 10 to 20% in space required. Critical signal-level circuits need no longer be individually adjusted for uniform, interwire capacitances. Maintenance and repair are easier and less costly, because modular construction allows fast replacement of panels in service.

Custom-extruded shapes can be supplied by

brass mills to reduce the time and cost of machining. For instance, a watchmaker buys extruded brass shapes and slices pieces from them to a desired thickness ready for finish machining to wrist watch cases. The slicing operation from the custom extrusion is a cost-cutting alternative to the blanking, milling and drilling necessary in making the case from ordinary bar stock.

In another example, the cost of a part in a hinge assembly (see Fig. 3) for Northrop's Talon supersonic trainer was reduced 40% by switching to an extrusion. When machined from solid brass bar, the cost of the part was $86. Use of the extrusion cut the price to $51.

Overcoming the Producibility Barrier... *by More Suitable Selection of . . .*

Stainless Steels

*By RICHARD E. PARET**

HARDENABLE "AUSTENITIC" stainless alloys have gained in importance over the past 12 months. For example, the B-70 Valkyrie "chemical" bomber, which employs one such alloy as the main sheet construction material, will travel at speeds up to 2700 miles per hr. without suffering damage from intense air-friction heat. In proper designs, these hardenable alloys provide high strength and hardness with excellent resistance to corrosion. They have good formability, and can be hardened at temperatures low enough to minimize distortion and oxidation.

Nuclear Use

Low cobalt content in stainless steel for nuclear use is desired because of the ravaging influence of irradiation. Were cobalt content not restricted, corrosion products containing cobalt-60 could pose serious maintenance problems and hazards to personnel doing repair work. Cobalt-60 also may move out of the stainless alloy and contaminate the entire primary loop of the nuclear system. Now commercial quantities of austenitic Type 304 L may be ordered with cobalt controlled to a value acceptable for use within the core of a reactor—perhaps as low as 0.005%.

A second development of significance to nuclear engineers is boron-treated stainless alloys. Type 304 L with about 2% boron possesses high thermal neutron absorption, good structural stability at 500° F. under irradiation, and good corrosion resistance.

Until recently, this alloy has not been commercially available. The metal was formerly melted in vacuum furnaces, and heats were limited to less than 4000 lb. Electric furnace melting can now produce heats of 24,000 to 28,000 lb.

A third stainless steel development may prove useful not only for nuclear reactors but also in other high-temperature applications. Nitrogen is closely controlled (0.3 to 0.5%) and chromium, nickel and manganese levels are maintained at a 22:4:9 ratio. The alloy resists erosion, oxidation and corrosion at temperatures up to 1600° F. Tensile strength exceeds 162,000 psi. at room temperature. Rupture strength decreases to about 50,000 psi. at 1100° F. in extended service.

Type 316 Improved

Important to corrosion engineers in the process industry is the development of a modified Type 316, termed alloy D-319. Over the past 15 years, several users have tested D-319. Both Tennessee Eastman Co. and E. I. du Pont de Nemours & Co., Inc., have verified test results: Close control of constituents of Type 316 will substantially improve its corrosion resistance and service life.

Chemical processing firms now accept alloy D-319 as slightly preferable to Type 316. The American Society of Mechanical Engineers has accepted D-319 within the framework of its

*Stainless Steel Specialist, American Iron and Steel Institute, New York.

Fig. 1 — New Buses Designed by Mack Trucks, Inc., Will Be Protected by Bumpers Clad With Stainless Steel (Type 301). Here workmen at Parish Pressed Steel Div., Dana Corp., remove one of the bumpers from a 1000-ton capacity press which formed it in one stroke. Made from mild steel clad on both sides with stainless, the bumpers are 0.118 in. thick, 17¼ in. wide, and 109 in. long. Trimming is not necessary after they are formed. (Courtesy of Allegheny Ludlum Steel Corp.)

boiler, pressure and oil pipe codes. The low-carbon version, D-319 L, also is being approved under the A.S.M.E. pressure vessel code.

Nitrogen Strengthens Type 301

Metallurgists have been aware for many years that the mechanical properties of Type 301 stainless could be enhanced by increasing the carbon or lowering the nickel content. Earlier attempts at such modification, however, resulted in a steel which work hardened rapidly. This trait limited the range of cold reductions at which the most desirable combination of strength and ductility could be obtained.

Recent investigations now suggest that the high work hardening rate of Type 301 can be controlled by reducing the nickel and simultaneously increasing nitrogen content. Stainless Type 301 modified in this manner exhibits higher ductility at a given strength level than does standard Type 301. Modified Type 301 also appears suitable for high-temperature service in the 800 to 1200° F. range. Possible uses include wing and skin surfaces, honeycomb skins, tail cones, bearings, cowlings and some shrouds.

Sandwich Rolling

Announced in December 1957, "sandwich" rolling has progressed beyond the experimental stage. In this process, several stainless plates are sandwiched between two carbon steel cover plates. After its edges are welded, the sandwich is heated and hot rolled on a conventional plate rolling mill. Typical sheets are 0.075 in. thick, 120 in. wide, and 240 in. long. Since the sheets do not contact the atmosphere during hot rolling and annealing, decarburization is negligible.

Stainless steel foil is available down to 0.0005 in. thick. Applications include honeycomb skins, electronic tubes, and missile and satellite instrumentation. Stainless foil 2 mils thick has been thinly coated with titanium activated with tritium for use as a radiation source.

Improvements in Fabrication

Cold roll flowing of stainless steel offers weight reduction and better uniformity of mechanical properties in all directions. Like metal spinning, roll flowing contours parts by cold shaping over a mandrel. Roller pressures above 200,000 psi. displace the stainless until it assumes the desired wall thickness and design contours. Frequently, the process will reduce or eliminate need for machining or welding. In fabrication of several hundred 3-in. O.D. stainless steel shells, 7 in. long, for example, roll flowing plus a re-forming operation reduced costs by one third and saved the fabricator about $1 per piece.

The narrow and variable band between yield point and ultimate strength in certain alloys prevents them from being formed by conventional methods. New stretch forming equipment compensates for yield strength variations in these high-alloy stainless grades, and permits stretch

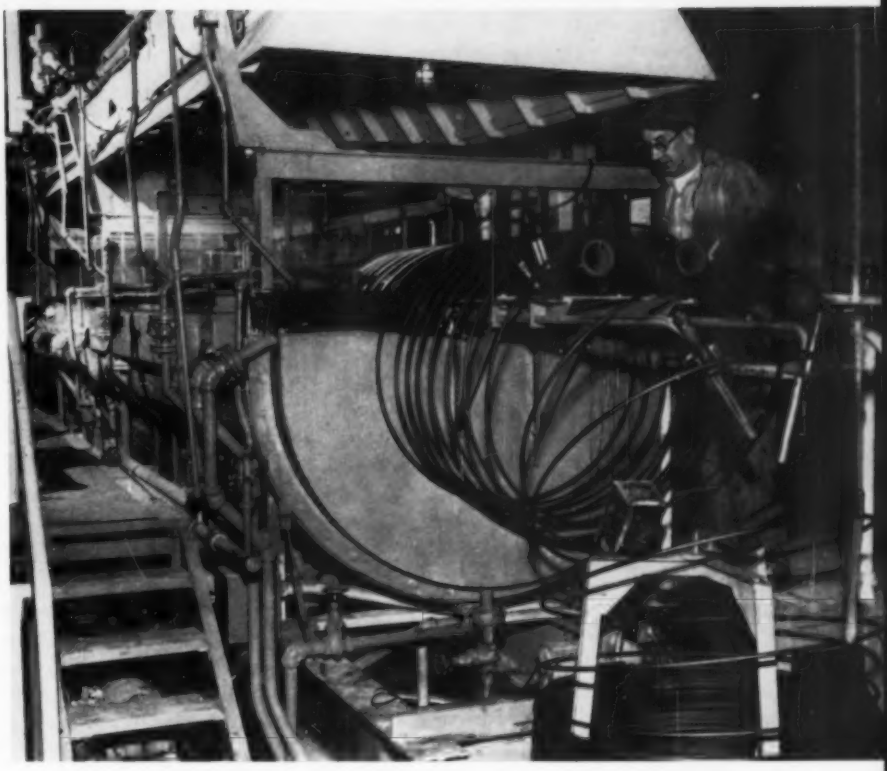


Fig. 2 – Electrolytic Plating Machine at Republic Steel's Massillon, Ohio, Plant Is the First of Its Type Installed for Copper Plating Stainless Cold Heading Wire. Unit deposits a 0.0002-in. thick coating which serves as a lubricant during cold heading

forming without tearing of sheets. The ultimate answer, of course, lies not in machine refinements but closer control of yield strength variations by steel producers. Progress is being made here.

In wiredrawing, it's reported that molybdenum disulphide improves drawability of Type 430 stainless. This solid lubricant not only resists high temperatures but also has superior resistance to die pressure and excellent lubricating properties. Metallic soaps and metallic lead drawing compounds, formerly employed, did not always give adequate lubrication.

Hot Extrusion

Stainless extrusions differ from rolled or drawn shapes in several important respects, most significant of which is the availability of complex contours, including deep undercuts, that were previously not possible in stainless steel.

Cost of tooling for hot extrusion is low – about $175. (See p. 114.) Compare this with the cost of rolls to make nonstandard sections – $1000 to $10,000. Thus, with short production runs, hot extrusions may be more economical. Petroleum refiners, chemical processers, aircraft makers and nuclear engineers frequently require special stainless steel tubular shapes with dissimilar inside and outside contours. These can be extruded in long lengths by the new process.

Earlier this technique was thought suitable only for mass production of standard sections. Now many roll formers claim the ability to produce standard stainless shapes on a job shop basis at relatively low cost.

Stainless structural members in Union Carbide's office building now being built in New York City are roll formed. In a number of instances, stainless roll-formed sections are chosen in competitive bidding over extrusions of other materials.

Roll-formed sections at lower cost are a distinct prospect because of die standardization. Dies represent a substantial proportion of the total cost of roll-formed sections and these costs can be apportioned over more than one job if customers buy stainless sections formed by combining a number of individual but standard dies.

One roll former supplies stainless trim for household refrigerators. Later with only one additional forming die he filled the order of another appliance manufacturer for stainless steel oven and range trim.

There are now 25 standard electrode compositions, as well as a number of special types. Several years ago, stainless electrodes were available only in 18-8, 25-12 and 25-20 compositions.

Copper and stainless steel can be joined by welding. Proper technique calls for beveling both copper and stainless steel plates to provide an included angle of about 80°. After heating the copper to 1000° F., its beveled surface is covered with a copper-nickel weld. Welding of stainless to copper plate proceeds in almost conventional manner. The resulting bond is strong, ductile and sound.

Experience with the hardenable "austenitic" stainless grades indicates that these alloys are also fully weldable by the same techniques and processes currently used for the austenitic stainless steels. Postweld annealing of joints at 1710° F. restores the loss in properties frequently encountered. Mechanical tests on fusion welds 0.024 to 1 in. thick show joint efficiencies of 90 to 100% over a range of tests from room temperature to 900° F.

Resistance welding of stainless alloys has been favored as a joining method for many years because the high electrical resistance of stainless facilititates rapid, distortion-free welds. Many fabricators, however, have reported difficulty in adjusting equipment to spot weld stainless without leaving indentations or residual weld marks. Equipment now is available which, it is claimed, eliminates the problem. Closely controlled weld time, coupled with transformers of special design, permit this. It finds wide use in the joining of Type 430 stainless for automotive bright work.

Cutting Is Cleaner

Tungsten-arc cutting of stainless has long found use among producers. Fabricators and distributors, however, have been reluctant to adopt the technique. Shape-cutting equipment currently available makes complex shapes on the warehouse floor, with little waste. In comparison with powder-cut plate, stainless cut with tungsten arc is cleaner, without iron-powder contamination, and has little or no carbide precipitation. Edge machining frequently is not required.

Honeycomb Structures

One fabricator finds silver brazing feasible in a gas-fired radiant furnace. The stainless steel honeycomb and skin are assembled and placed within a foil envelope. Air is withdrawn and a suitable brazing atmosphere is introduced. The assembly is mounted in a fixture, preheated to 1100° F. and automatically pulled through the furnace where joining takes place at 1750° F.

In another method, flexible electric heating blankets are employed to heat honeycombs to brazing temperature. A wire mesh resistance heater within a blanket of high-temperature silica is placed directly against the outer skin of the stainless. Brazing of irregular shapes and thin-edged honeycomb, which tends to distort in a furnace, are potential applications of this joining technique.

Overcoming the Producibility Barrier . . . ***by More Suitable Selection of . . .***

Magnesium Alloys

*By T. E. LEONTIS**

FIGURE 1 illustrates an example of how magnesium is coming of age as an everyday metal. Modern lightweight luggage capable of taking the bumps and bruises of rough handling is being made from magnesium extrusions and hot formed sheet by Shwayder Bros., Inc., Denver. The Silhouette design is produced at the rate of 3000 pieces per day in the world's largest hot forming operation for magnesium. Its basic structure consists of two drawn magnesium shells and two bent tongue-and-groove magnesium extrusions. These parts are formed at 350 to 500° F.

*Metallurgical Laboratory, Dow Metals Products Co., a division of Dow Chemical Co., Midland, Mich.

Fig. 1 – Modern Luggage Made From Magnesium Extrusions and Hot Formed Sheet

Shwayder selected magnesium because it combines light weight with resistance to denting and fracturing.

Use of wrought forms of magnesium alloys is expanding for such commercial items as ladders, scaffolding, tools, furniture, concrete wall pouring forms, materials handling equipment, and for office machines.

Fig. 2 – Strength of New Alloy (ZE 10 A) Permits Its Fabrication Into Large Structures. Stress-relieving is not necessary after welding

Wide Sheet and Plate Available

Although alloys containing aluminum and zinc continue to be the backbone of the magnesium industry, several new compositions and the operation of a modern rolling mill and extrusion plant (Dow Metal Products Co., Madison, Ill.) are stimulating the use of magnesium in commercial applications. The new facilities produce sheet and plate, both flat and coiled, in widths ranging up to 72 in.

The extrusion plant is

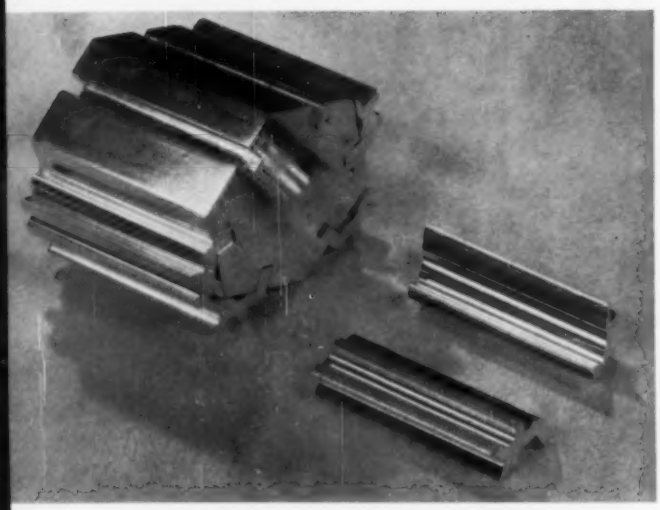


Fig. 3 – New Wrought Magnesium Product, the Precision Extrusion, Here Used in the Spacer of a Paper-Cutting Machine

equipped with presses of 250 to 5500 tons capacity and a heavy press of 13,200 tons capacity.

Applications

Magnesium alloy AZ 31 B (3% Al, 1% Zn) is employed as tooling plate. Available in thicknesses from ¼ to 6 in., it costs less than other lightweight tooling metals. Flatness of the as-rolled plate is satisfactory for tooling purposes. Magnesium treadplate, also rolled directly, is made into dock boards, platforms, and mechanical handling equipment where strength, light weight, ruggedness and long life are required.

Alloy ZE 10 A (1.7% Zn, 0.17% rare earth metals) is a new sheet composition. Unlike AZ 31 B, stress-relieving after welding is not necessary. This advantage, when combined with the good strength (38,000 psi. tensile, 28,000 psi. yield, 15% elongation), and the excellent weldability of the alloy, promises high productivity of large structural assemblies. Large storage bins made by Tote Systems, Inc., (Fig. 2) are fabricated of ZE 10 A sheet.

A new magnesium wrought product – the precision extrusion – can be made with dimensional tolerances formerly obtained only by extensive machining. Figure 3 shows the application of two precision extruded shapes in the spacing mechanism of a paper-cutting machine.

Magnesium die casting has advanced with the development of an automatic process for feeding metered quantities of molten magnesium into the shot well of a cold chamber die-casting machine. Alloys AZ 91 A and AZ 91 B, a slightly different composition, are used in a broad range of die-casting applications, mostly commercial. Examples include automotive parts, electric motor end frames, camera and projector parts, portable tools, electrical connection plugs, tape reels and missile parts.

The biggest gains for magnesium have been in airframes and missiles. In *Metal Progress* next month, developments in these fields will be discussed and a data sheet will cover commercial magnesium alloys, their properties and uses.

Overcoming the Producibility Barrier...

by More Suitable Selection of . . .

Wrought Aluminum Alloys

*By E. P. WHITE, R. C. KASSER and L. M. DUNN**

WROUGHT ALUMINUM-MAGNESIUM alloys are gaining more prominence in welded structures with the perfection of inert-gas-shielded arc welding. This method eliminates the need for fluxes; it concentrates the heat better and reduces cracking. Welds are strong and ductile. Tank trailers and dump truck bodies (Fig. 1) can now be made by welding these strong aluminum alloys – such as 5154 and 5086. Tank trailers fabricated from them have been satisfactory for carrying

*Development Engineers, Aluminum Co. of America, Pittsburgh.

Fig. 1 – Built of Welded Aluminum Sheet (Alloy 5154) no Thicker Than the Steel Used Before, This Truck Body – Capacity 18 Cu. Yd. – Weighs Only 7400 Lb. and Can Haul 30% More Load. Truck has been operating for three years at a Pennsylvania strip mine

nitrogen fertilizer solutions, sugar syrups, and high-octane gasoline.

There remains one restriction in the use of 5154 and 5086 – corrosion resistance at elevated temperatures is not satisfactory. However, another aluminum-magnesium alloy – 5454 – is comparable in strength to 5154 and 5086 alloys (Table I) but has better resistance to corrosion. Tanks made of this new alloy can haul hot oil and asphalt, foodstuffs, and other commodities at temperatures up to 450° F.

In addition to tank trailers, the trucking industry has applied the aluminum-magnesium alloys to welded dump truck bodies. For example, aluminum dump trailers 40 ft. long haul uranium ore in the Rocky Mountains over rough unpaved roads and concrete highways. A fleet of 16 exhaust-heated dump bodies has also been fabricated of welded 5454. These units, the largest of their kind, are heated with exhaust gases to help dump wet sticky ore.

Table I – Typical Properties of Weldable Aluminum-Magnesium Alloys

Alloy and Temper	Ultimate Strength	Yield Strength	Elongation in 2 In.
5052	28,000 psi.	13,000	25%
5052-H32	33,000	28,000	12
5052-H34	38,000	31,000	10
5154-0	35,000	17,000	27
5154-H32	39,000	30,000	15
5154-H34	42,000	33,000	13
5154-H112	35,000	17,000	25
5454-0	36,000	17,000	22
5454-H32	40,000	30,000	10
5454-H34	44,000	35,000	10
5454-H112	36,000	18,000	18
5086-0	38,000	17,000	22
5086-H32	42,000	30,000	12
5086-H34	47,000	37,000	10
5086-H112	39,000	19,000	14
5456-0	45,000	23,000	24
5456-H321	51,000	37,000	16

Another new alloy – 5456 – is recommended for construction of huge bottom-dump trailers for rugged off-highway rock hauling. Average tensile strength across welds is 46,000 psi. and free bend elongation is 28%. Seven bottom-dump trailers, each with 80 cu.yd. capacity, have been built with this alloy welded with 5556 filler wire. These mammoth units are expected to go into service within the next few months.

Passenger Cars – Use of aluminum in the 1959 passenger cars is expected to reach 283 million lb. Each auto carries an average of 51½ lb. of aluminum. About 10 lb. of this is trim or decorative parts made from three low-magnesium alloys of high purity (5357, 5457, 5557). Alloy 5557, the newest alloy, gives the most lustrous anodized finish. Although European auto makers have used aluminum trim for years, they found

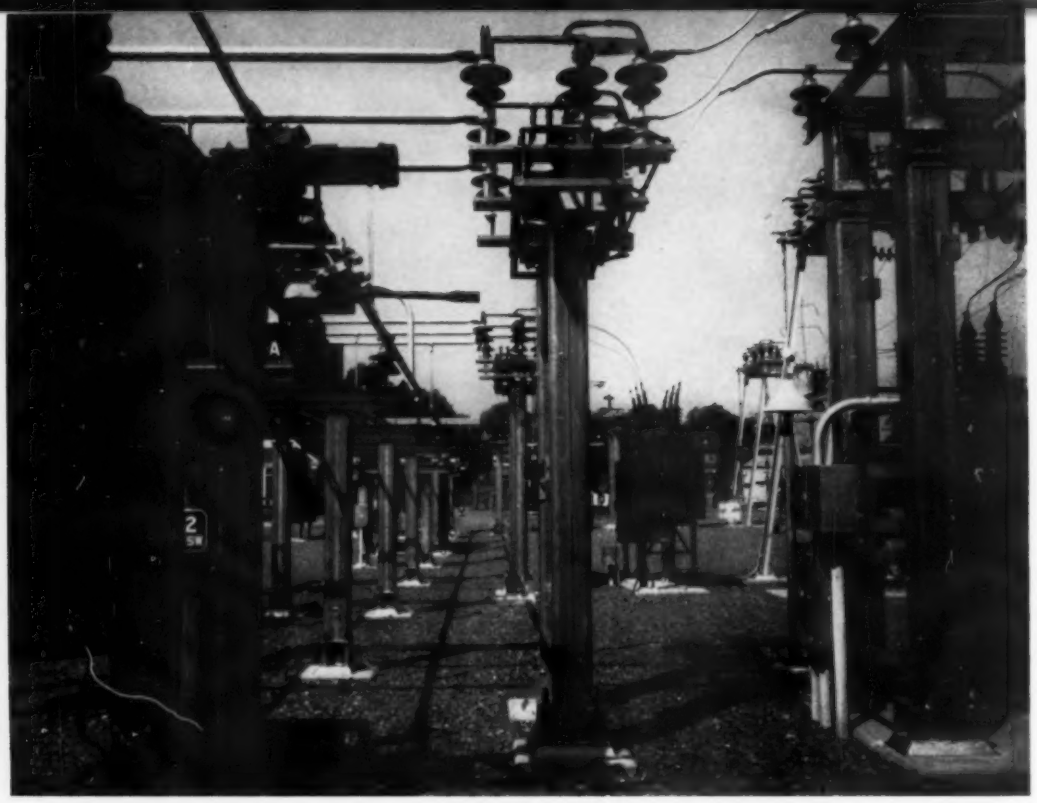


Fig. 2 – Philadelphia Electric Co. Switched to Aluminum Structures at One of Its Power Stations. Components were fabricated by welding rectangular tubing

it impossible to obtain the high luster typical of chromium plate without turning to anodized super-purity aluminum. There is one disadvantage – super-purity aluminum is expensive. However, with special alloying techniques and improved mill practices, these bright long-lasting finishes for aluminum are possible at competitive prices. Standard moldings are now specified in 5357, 5457, and 5557 aluminum alloys. Emphasis is on lighter automobiles and new style features, and it is expected that aluminum bumpers will be the next major breakthrough for this family of alloys which can be anodized to a highly lustrous finish.

Structures – Highway construction has stimulated the use of aluminum. With few exceptions, aluminum has become the material for lighting standards and luminaires, signs, and bridge railings (200,000 ft. of aluminum railings were installed on the Ohio Turnpike alone). Lower maintenance cost is an important factor here. Castings and tubes are assembled to make railings; lighting standards are tapered shafts spun from aluminum tubes with brackets attached by bolts through welded fittings.

Aluminum has been making gains in bridge construction also. A continuous four-span bridge, 222 ft. long, was erected in Iowa during 1958. Most of the components of the plate girder span were prefabricated in the shop by welding and later joined at the construction site by bolting. Principles of aircraft design are being applied to bridge construction by Fairchild Engine and Airplane Corp.

Utility companies in highly industrialized areas where maintenance of galvanized steel has proved costly have long used aluminum for substation structures (Fig. 2). Recent advances in welding are widening this application. Aluminum transmission towers, planned for future construction, will be made of standard shapes bolted together.

Ribbed aluminum roofing sheets can now be used to span open roof-supporting systems, thus eliminating the need for the continuous wood roof deck which has been used in home construction for centuries.

In a recently constructed hospital, extruded "T" stiffeners support the ⅛-in. thick panels which make up the exterior curtain wall. The stiffeners are bolted to studs which have been welded to the backs of thin panels. Evidence of welding cannot be seen on the front of the panels.

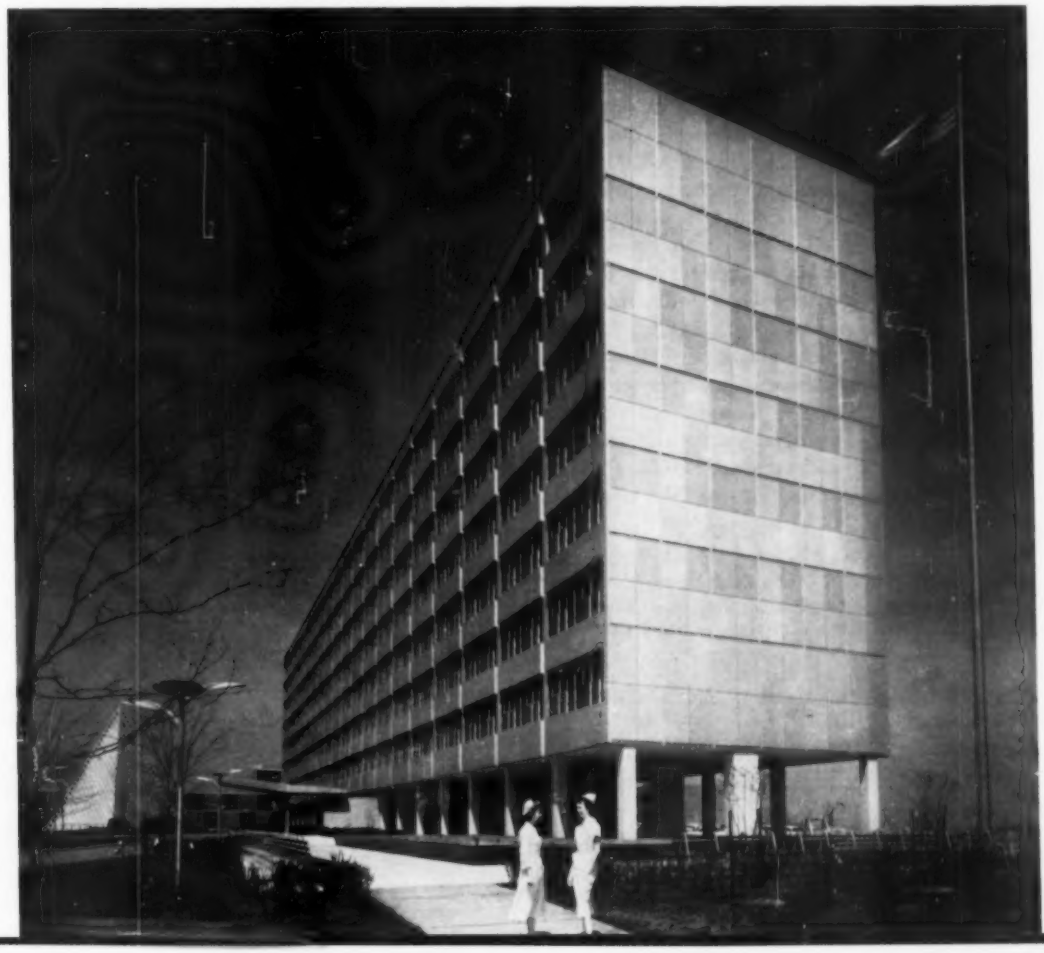
A new sandwich panel is now available. Foamed polystyrene is bonded on one or both sides to aluminum sheet. Other materials such as

Fig. 3 – New Finish for Aluminum Sheet Depends on Grain Growth to Give Spangle Effect

plywood, hardboard or cement asbestos board can be bonded to the foam core either as a back-up for the aluminum facing or as the facing on one side.

Finishes – The application of porcelain enamel to aluminum has become practical within the last decade with the development of low-firing frits. Materials and methods have also been developed for anodizing aluminum for exterior application. Recent advances in baked enamels have made available siding and roofing protected with this finish for home construction.

Fig. 4 – This Curtain Wall Is Supported by Extruded "T" Stiffeners Attached by Aluminum Bolts Welded to the Inside Surface of the Panels. Although the curtain wall is only ⅛ in. thick, it shows no evidence of welding on the outside surface



Research has led to new alloys for clear anodic finishes which preserve the natural beauty of aluminum with few surface imperfections. Certain alloy constituents also provide integrally colored surfaces after anodizing. The most widely used alloys of this type are those which produce various shades of gray. In addition, progress is being made with alloys which when anodized will be tinted with shades of gold.

Additional forms of aluminum sheet are also being introduced. For sheet which is embossed – either one or both sides – the trend seems to be toward large, bold patterns. A way has been found to combine production and finishing techniques to take advantage of grain growth. Relatively large grains, purposely produced, provide an attractive spangle effect on sheet surfaces (see Fig. 3).

Overcoming the Producibility Barrier... ***by More Suitable Selection of . . .***

Carbon and Alloy Steels

STEELMAKERS EXPECT that applications for heat treated constructional alloy steels will increase sharply in the next few years. Although they cost more than carbon grades, their greater strength-to-weight ratios permit significant weight savings. Alloy steels are definitely not universal substitutes for carbon structural grades, but they fit into the picture where strength and weight are prime factors. The Carquinez Straits Bridge across one arm of San Francisco Bay illustrates sensible design with three structural steels of various strength levels. Roughly 6500 tons of carbon steel (A-7) were used in the lower-strength members, and 5400 tons of a high-strength low-alloy grade (A.S.T.M. A-242) were employed in medium-strength areas. Highly stressed members weighing 2900 tons were made from "T-1" constructional alloy steel.

Use of alloy steel in major tension and compression members of structures permitted significant weight saving. Weight reduction effected by using three steels in the design of this bridge saved an estimated $800,000. For example, where 1½-in. sections of "T-1" were employed, carbon steel sections on the order of 3¼ in. would have been required.

Columbium-bearing steels also offer potential savings in weight and cost. Available in hot rolled sheet, these mild steel grades rely on the addition of columbium for high strength and good weldability.

Greater use of steels with higher carbon and manganese content for heat treated parts has resulted in a need for more hardenability data. These steels are sometimes substituted for the lower-alloy grades. For example, C-1041 steel has replaced some of the steels in the 1300 series. Work has been under way to establish hardenability bands for C-1041 and C-1045, and data should be available soon.

Where the cheaper carbon steel will not do the job it becomes necessary to turn to the alloy grades for greater strength. In one instance a tractor manufacturer changed from a 1046 steel to a modified 1335 grade containing 0.35% C and 1.50% Mn for links and rollers for one of its lines.

More emphasis is being placed on improved notch toughness to prevent brittle fracture in service. Surveys show that low carbon, phosphorus, and nitrogen contents in unhardened pearlitic steels yield best toughness, particularly if the manganese, nickel, silicon, and aluminum levels are raised and fine ferritic grain size is maintained. In general, the lower the temperature of transformation of heat treated steels, the better the toughness. To develop superior notch

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toughness when the transformation is low, tempering is required, but the various types of tempering embrittlement must be avoided. Even then, small amounts of the products which form at high transformation temperatures (pearlite and upper bainites) may seriously impair the toughness of tempered martensitic steels.

Hydrogen in Forgings

The forging industry has known for some time that small amounts of hydrogen have an adverse effect on ductility and on susceptibility to flaking in forging steels (see *Metal Progress,* July 1959, p. 72). Experimental work has shown that moisture content of the steelmaking furnace atmosphere, the slag basicity, and the degree of oxidation of the slag-metal system largely control the hydrogen content of the liquid steel during basic electric steelmaking. Close control of these variables results in hydrogen contents of 2 to 3 ppm. However, at this level extensive heat treatment to prevent flaking is still required.

Vacuum casting can reduce hydrogen to about 1 ppm. Forgings made from vacuum-cast ingots have little or no susceptibility to flaking. Ingots 110 in. in diameter and weighing up to 235 tons can be made. Tests indicate that the hydrogen level is about 80% lower than in forgings made from ingots cast in air.

Consumable-electrode vacuum melting, formerly restricted to production of high-quality aircraft steel, may find more commercial use in the near future. There appears to be less variation in the transverse and longitudinal properties – particularly reduction in area – in rolled and forged metal made from arc melted consumable electrode vacuum-cast ingots. Vacuum arc melting apparently breaks up and redistributes the nonmetallics, an effect which may well account for the improvement in directional uniformity. Bearing manufacturers are interested in the process because it may be one way for them to get better reliability from their product, especially in mill bearings, and diesel engine bearings where failure of parts causes long and expensive shutdowns or safety hazards.

Cold finished bars may be the answer to producibility problems where high strength (above 100,000 psi.) and machinability are required. These steels are basically the C-1144 grade, cold drawn for good strength, and stress-relieved to control after-machining distortion. They have been replacing alloy grades 4140 and 8620 in applications where impact strength is not critical. These steels are most economically used where the high hardness level of the bar is sufficient to eliminate the need for heat treatment after machining. One producer of portable electric tools now makes some of its shafts, gears and pinions from cold finished bar steel. Production costs have dropped because it is less expensive, it machines faster, and heat treatment is not necessary or has been decreased from what was previously required with a low-alloy steel.

Elevated-Temperature Drawing

In one of the newer developments in bar production, drawing is carried out at "warm" temperatures below crystallization. Warm drawing imparts higher strength to bar stock than is commercially practicable by cold drawing and strain relieving. Limited now to C-1144, it is expected that the process will be extended to the production of bars of other compositions.

Larger Coils

To keep pace with the desires of fabricators who want to use coil rather than cut sheets, steel companies are carrying on a continuing program to revamp rolling mills. Can manufacturers, for example, are making greater use of coil steel. Demand for larger coils apparently stems from automated production which reduces handling costs and takes full advantage of the continuous blanking and forming operations. Large coils also reduce costs by eliminating the need for heavy inventories of various sized sheets because they can be slit and sheared to smaller sizes. Also, producers of cold headed parts get more producibility from larger wire coils because downtime is less.

Steels for Automobiles

In the auto industry some alloy steel parts have been changed to carbon steel without sacrificing reliability. This has occurred generally where sections are light and where improved heat treating practice can be employed to enhance the mechanical properties of carbon steels. In some instances, the change from alloy to carbon steel for a specific application has actually improved the performance of the part. For example, rear axles are now made of C-1045 by at least one auto maker because fatigue life is better than if they were made of alloy steel.

But the weight of alloy steels per unit in the lower-priced automobiles still exceeds that in the more expensive models. While alloy steels are not necessary in some parts, the switch to cheaper carbon grades would require a tremen-

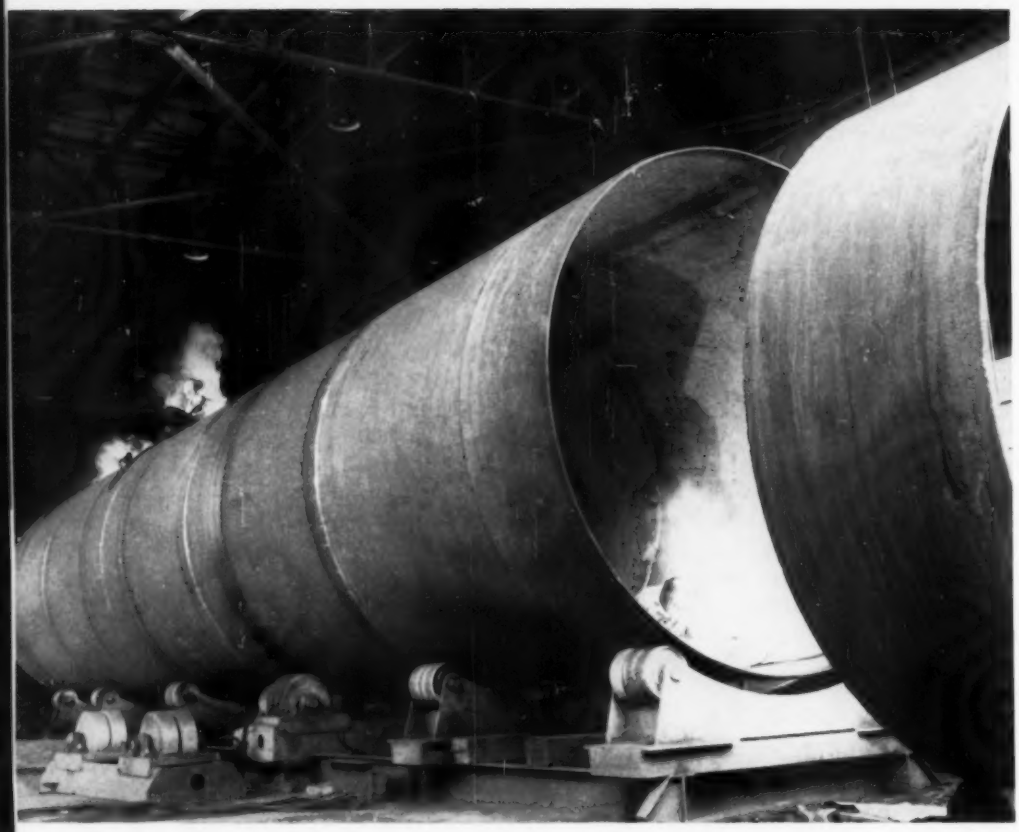


Fig. 1 — Use of Alloy Steels in Large Structures Can Result in Lower Costs. Shown above is a large air accumulator (50,000-gal. capacity) being constructed of "T-1" plate supplied by Lukens Steel Co., Coatesville, Pa. Strength of the vessel's walls is the same as it would be if made of heavier-gage mild steel plate. Construction is quicker because the thinner plates can be welded with fewer passes. The tank, which is 65 ft. high and 11 ft. in diameter, is hydrostatically tested for a working pressure of 585 psi. at −20 to 125° F. Welds are X-ray inspected 100%

dous increase in the cost of inspection. Auto makers are improving heat treating techniques (better temperature control, rapid induction heat treatment, less transfer time to quenching medium) and part design. This will permit a change to the cheaper carbon steels in more parts.

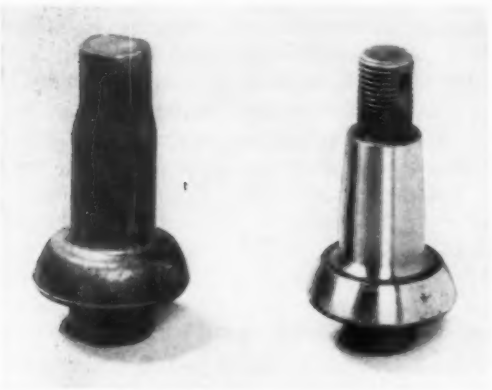
In applications which demand that parts be easily machined as well as weldable, the low-sulphur leaded carbon steels have gained. Experience has shown that lead in steel is not as detrimental to welding characteristics as sulphur.

Where the shape of a part is more important than its strength, economic increases in production rates are possible with a resulphurized, rephosphorized, leaded carbon steel (12 L 14). Allowable machine speeds are often not high enough to take advantage of the excellent machinability of this steel. Some shops have switched to 12 L 14 rather than buy new machines to increase production rate. One reason for the growth of the list of leaded steels and their application is the fact that automatic machines can be set up to handle hot rolled stock even though dimensional variations are greater than in cold drawn bars.

Cold Heading

Cold heading and cold extrusion continue to grow in importance. Neither machining nor heat treatment may be required after the part has been formed. For the cold heading process carbon steels such as the 1008, 1010, 1018, 1020, 1022, 1035, 1038, 1041 and 1045 grades are being used most. Low-carbon steels are employed where strength is not critical. They may require stress-relief after heading. For automobiles such

Front End Suspension Part



Cold headed parts are getting larger. This automobile part, made of 8640 steel, was cold headed (left), then machined to the finished piece (right). It was heated to 1500° F., oil quenched, and tempered at 900° F. for at least 1 hr. to Rockwell C-30 to 36. Use of alloy steel in this application provides a high safety factor. (Source — K. J. Sorace, Lamson & Sessions Co.)

items as cylinder head bolts, body bolts and front end parts are made of quenched and tempered 1045. If strength is desired and the cheaper carbon steels will not do the job, designers specify alloy steels such as 8640 (suspension balls), 4037 (aircraft applications), and 1335. In carbon steels, auto parts such as spark plug shells and stoplight switch housings, which require machining after forming, can be economically made by cold heading a resulphurized rimming grade C-1110. Surface of bar stock is excellent.

A new grade, actually a modified C-1012 grade with lower carbon and higher manganese, has recently appeared as a bar product for cold extrusion of parts which will later be carburized.

Warm Heading

Applications of warm heading are expanding. Increased formability at warm temperatures means that sharper corners can be made on the part with less pressure. Fractures due to severe forming are often eliminated. Metals formerly not considered for room-temperature forming, such as 52100 and other high-alloy and high-carbon grades, can be warm headed. Production of some of the more difficult alloys can be done on faster machines and die life is improved. In one instance in producing a small part from 1006 by warm heading at 240° F. using resistance heating, tool life was increased from 4500 pieces to over 50,000 pieces per tool change.*

Electrical Steel

One of the new developments in carbon electrical steels stems from the growth of the basic oxygen process which gives steel with lower content of nonmetallics, sulphur and nitrogen. Lower-cost carbon steels are now available to replace certain of the silicon-bearing grades which have electrical and magnetic properties suitable for use in fractional horsepower motors.

Finishes

Automobile corrosion has become more serious in recent years with greater use of highly corrosive salts on roads for ice and snow removal. One answer to the problem is to smooth out bumpers and sheet metal panels, thus reducing the number of pockets. Smoother designs increase the uniformity of the electroplated coatings. But auto makers are also looking into new types of surface protection such as zinc chromate primers applied before or after forming, different zinc coatings (heavy on the exposed side but lighter on the other to maintain weldability at high production rates). Aluminized wire and sheet and stainless clad bumpers (see picture on p. 132) have had limited but growing use.

Users of galvanized sheet have come up with some new applications (clothes dryer baskets, automobile mufflers) based on corrosion resistance of the sheet and its formability. Formation of the brittle Fe-Zn alloy between the zinc and steel is inhibited during coating thus permitting severe drawing without flaking. In some instances the galvanized sheet has been formed by spinning.

Applications of vinyl-coated steel (*Metal Progress*, March 1959, p. 126) increased during the past year. This product is made by bonding a plastic, as a liquid or as cured sheet, to cold rolled or galvanized steel sheet. The plastic can be embossed with numerous designs. Sheet can be formed by the same methods as ordinary cold rolled sheet without damaging the bond or the surface texture except in extreme drawing when some "wiping" of the plastic coating may occur at sharp turns.

*Information supplied by Herbert E. Peterman, Herscott Corp., Rockford, Ill.

Fallout From Nuclear Weapons Tests

THE JOINT COMMITTEE ON ATOMIC ENERGY of the U.S. Congress has issued a summary of its public hearings on the above topic in 1957, and again early in May 1959. A group of 12 scientists planned the second hearing and some 30 experts testified. In addition, a panel of 22 scientists appraised the predictions made in 1957 in the light of information gained since then.

The three wartime explosions at Alamagordo, Nagasaki and Hiroshima were relatively small – each about 20,000 tons TNT equivalent or a total of 60 kilotons. Since then tests have been made as follows:

TIME	U.S. AND U.K.	U.S.S.R.
1945-1951	700	60
1952-1954	37,000	500
1955-1956	9,200	4,000
1957-1958	19,000	21,000

This gives a total of 91,460 kilotons "fission yield equivalent", released to date. About 21,500 kilotons was in ground surface bursts in which about 80% of the debris is deposited nearby, 32,500 in water surface bursts in which about 50% of the debris falls back into the ocean near the site, and 37,500 in air bursts. That portion of the impalpable dust which becomes air-borne will eventually be washed down by rain, and if a heavy rain coincides with the passage of a loaded air mass, localized "hot spots" will cover a county, a milkshed or even a state, where concentrations of radioactive elements two to three times that in adjacent areas may be found. In any event the time the debris is air-borne is too short for any appreciable amount of radioactive decay, except perhaps for I^{131} and Ba^{140} of short half-life. It is now believed that the "mean residence time" of that portion of the debris which rises into the stratosphere is one to five years (rather than the five to ten years estimated in the 1957 hearings, and with correspondingly less of the total radiation occurring up there where it is biologically harmless). In any event the long-lived Sr^{90} and Cs^{137} get down to earth about as radioactive as when they were originally formed.

In the earlier hearings most emphasis was put on these isotopes of strontium and cesium. Now the associated short-lived isotopes are thought, under certain circumstances, to be equally suspect.* Likewise radioactive carbon – formed naturally by collisions between cosmic rays and atmospheric nitrogen, and in bomb bursts by neutron bombardment of nitrogen – is thought to be significant. The half-lives, and the 10 half-lives which allow 99.9% of the radioactivity to decay, are given in the following table.

ISOTOPE	HALF-LIFE	10 HALF-LIVES
I^{131}	8.05 days	80.5 days
Ba^{140}	12.8 days	4.3 months
Sr^{89}	51 days	17 months
Zr^{95}	63.3 days	21 months
Cs^{144}	290 days	8 years
Sr^{90}	28 years	280 years
Cs^{137}	30 years	300 years
C^{14}	5600 years	56,000 years

Another important finding is that fallout is not uniformly distributed over the earth or even in the stratosphere. The Northern Hemisphere has received more than twice as much Sr^{90} as the Southern, and a high concentration between the 40 and 50° latitudes exists in both, with a much lower value at the equator. About one third of the debris has already reached the ground; two thirds is still in suspension. The Russian tests, conducted as they are in the higher latitudes, project radioactive dust into air currents which remain in the north latitudes, and this debris will be deposited almost entirely in the Northern Hemisphere after a mean residence time of about one year. "It is clear that the problem of world-wide fallout is dominated by atmospheric detonations of large-yield devices."

What does this mean to human beings? The race has evolved in such a way as to endure from birth to death a very considerable amount of radiation – "background" radiation due to cosmic rays, to C^{14} in the atmosphere, and from radioactive elements (principally uranium in granitic mountain masses). This natural background radiation varies considerably with geographic location and altitude, but is estimated at about 100 milli-roentgens per year for the bulk

*For example, more of the short-lived isotope Sr^{89} is produced in a fission reaction than the long-lived isotope Sr^{90}. It is possible that a local rain storm could wash these to the ground and foodstuffs be contaminated promptly. Since they are similar chemically, ingestion of such contaminated food may cause a higher radiation exposure for a short time from the Sr^{89} than that from the Sr^{90} for a long time. Such effects would be strictly local and have little significance as to world-wide fallout, which latter has meaning only in terms of the population as a whole and over a long period of time – dozens of generations.

of the persons now living – or a total of 7 to 10 roentgens in a lifetime. *Extra* radiation may cause somatic or genetic effects.

Somatic effects are those which affect the individual only and are not passed on to progeny. Representative examples are disease caused by preferential absorption of iodine in the thyroid, and leukemia or cancer due to absorption of strontium and cesium in the bones. Intense or prolonged exposure to X-rays is also damaging to the individual. While everyone believes that *large* doses are harmful, no one can clearly mark the threshold below which there is no increase in disease – or even if there is such a threshold. Leukemia and cancer were human scourges before any nuclear weapons were fired, and no one knows whether the 7 to 10 roentgens of radiation each adult experiences from natural causes or whether any one or more of a hundred other environmental conditions is responsible. Definitive studies of exceedingly large statistical samples of human population would be needed to give an answer. Experiments on laboratory animals indicate that low dosages or low rates are less effective than higher ones, and this points up one difficulty in relating the effects of laboratory testing to expected action on human beings.* The range of exposure of about 300,000 experimental animals was from 90 roentgens per min. to 90 roentgens per week; the lowest of these is about 50,000 times the natural rate of 7 to 10 roentgens in a lifetime. English studies indicate that children who received whole body radiation of 1 to 10 roentgens before birth while the mother was receiving abdominal X-rays have about twice the incidence of cancer and leukemia as do children whose mothers were not X-rayed during pregnancy. But again no studies have yet been reported where any significant number of humans have been exposed to radiation *slightly* over the natural background. (Fallout to date has the effect of increasing the world-wide natural background by about 4%.)

Genetic effects are changes in the genes, which are made up of extraordinarily complex organic molecules containing carbon atoms. X-rays and gamma radiation from ingested radioactive particles may permanently alter these; decay into nitrogen of an atom of radioactive carbon C^{14} in a molecule obviously changes or destroys that portion of the gene. "The genetic injury from both weapon-produced carbon-14 and fission products [or natural background] occurs at the moment the genetic molecule is affected. The actual effect does not appear until this particular gene is found in either the sperm or ovum at the time of fertilization. This event may occur several generations after the initial injury. While most of the injury due to radioactive fission products will be initiated within the first 30 years of a man's or a woman's life, injuries from C^{14} may be introduced over thousands of years" – that is to say, whenever an unstable C^{14} atom in a gene takes it upon itself to disintegrate. It will do no good to go to "clean" bombs, since about the same number of neutrons (and C^{14} generated thereby from atmospheric nitrogen) are produced in a fusion bomb as in a fission bomb of equal TNT equivalent.

The relative amount of radiation to which the inhabitants of the earth are subjected during the first 30 years of life is approximately 3000 milliroentgens from natural radiation background, of which 45 milli-roentgens are from C^{14} existing naturally. To this is now to be added 50 milliroentgens from existing fallout other than C^{14}. The total weapon-produced C^{14} is already sufficiently large so that its eventual genetic effect during the next 10,000 years will be from two to four times that of the fission products already existing.

In past discussions most of the genetic damage was considered to be due to the long-lived Sr^{90} carried down by rain. Almost 99% of it is retained by the soil and plants; only 1% gets into the water supply. Apparently some of it can be taken up directly by plants without going through soil. The plants are able to discriminate between strontium and its chemical cousin calcium to a certain degree, but the concentrations of Sr^{90} and Cs^{137} in milk and other foods is increasing more rapidly than would be expected from known values of fallout. Strontium, like calcium, finds its way into human bones and its radiation impairs the normal functioning of bone marrow – intimately concerned with production of red blood corpuscles. The present concentration of Sr^{90} in the bones of Americans averages 0.004 microcurie per gram of Ca, and this will rise by

(*Continued on p. 256*)

*The difficulty of relating laboratory experiments on animals to expected effects on humans is pointed up by the following quotation from a recent issue of "*The New Yorker*":

"Tea is the latest atomic-age drink. In Japan, mice that were fed tannic acid stored 30% less strontium in their bones than mice not given the acid. Tea contains tannic acid, as Japanese merchants were quick to point out. Whether a human bone acts like a mouse bone nobody knows for sure, not even a mouse."

Overcoming the Producibility Barrier . . .

by Better Use of Atmospheres in Heat Treating and Metal Processing

I—Trends in Atmospheres

IN TODAY'S INDUSTRIAL WORLD, metals engineers can solve many production problems by using the proper atmosphere. If bright annealing is needed, as with copper and stainless steel, an atmosphere can protect surfaces from oxidation. If forging billets are to be scale-free, a protective atmosphere in the heating furnace will do the job. If a hard surface is wanted, atmospheres that can carburize, carbo-nitride, or nitride are easily produced. In short, where surface treatment or protection is important, atmospheres are useful. In this article, we will show that they are becoming more useful all the time.

Because of the constantly changing industrial climate, it behooves metals engineers to become acquainted with all that is new about atmospheres and their control. While new metals are being devised, familiar metals are being improved, and all metals are being asked to meet stiffer specifications. More is being demanded of metals in every application. Knowledge of the latest developments in the atmosphere field will help all metals engineers who are engaged in the constant battle to produce a better product at a lower cost.

Types of Atmospheres

The most familiar types – dissociated ammonia, exothermic, and endothermic – are listed in Table I, along with analyses and comparative costs. To these we can add nitrogen and the inert gases (chiefly, argon) which may be obtained from the distillation of air. Along with dry hydrogen (used for special applications), this latter group has been considerably more expensive than those listed in the table, though the recent upsurge in the use of oxygen in steel refining has apparently added a much cheaper source of supply for nitrogen. More of this later. Vacuum is also classed as a protective atmosphere today.

As for case hardening atmospheres, gas carburizing, carbo-nitriding, and nitriding are familiar processes. A part can be carburized in an enriched endothermic or exothermic atmosphere. High-purity ammonia helps provide atmospheres for carbo-nitriding and nitriding.

Atmosphere Generators Are Improving

What are some of the new developments helping to solve problems with atmospheres? Various answers come from experts in the field. For instance, N. K. Koebel, Lindberg Engineering Co., says, "The only new approach to gas purification in the last ten years has been the application of 'Molecular Sieves' . . ." What is a molecular sieve? It is an artificial zeolite* (a mineral used for softening water) which, to purify nitrogen or hydrogen atmospheres, strains larger contaminating molecules from them. Lindberg uses this product (which is made and sold by Linde Co.) in their Hyni nitrogen generator to remove carbon dioxide, water vapor, sulphur dioxide, hydrogen

*Zeolites act through ion exchange mechanisms. In water softening the Na^+ radical of the zeolite compound is gradually replaced with the Ca^+ radical in the water salts. Molecular sieves are formed by heating crystalline sodium and calcium alumino-silicates to drive off water of hydration. When this water is gone, the crystal does not collapse. The physical structure remains stable, and a network of uniformly sized pores appears. These openings act as screens, trapping any molecules too large to go through them.

Table I – Typical Protective Atmospheres*

Type	Ratio of Air to Natural Gas	Composition					Dew Point	Cost Per 1000 Cu. Ft.†
		CO_2	CO	H_2	CH_4	N_2		
Dissociated ammonia, untreated‡	—	0.0	0.0	75.0	0.0	25.0	−40 to −60° F.	$1.05 or $3.95
Exothermic gas, unpurified								
Rich	6:1	5.0	10.0	15.0	1.0	69.0	Saturated	0.10
Lean	10.25:1	11.5	0.7	0.7	0.0	87.1	Saturated	0.08
Exothermic gas, purified								
Rich	6:1	0.0	10.5	15.5	1.0	73.0	−40	0.15
Lean	10.25:1	0.0	0.7	0.7	0.0	98.6	−40	0.13
Endothermic gas								
Dry	2.4:1	0.0	20.0	38.0	0.5	41.5	−10	0.19
Wet	3.5:1	2.0	17.0	28.0	0.0	53.0	Saturated	0.17

*Source: A. R. Ryan, Industrial Heating Dept., General Electric Co.

†Costs include only materials consumed, such as power, gas and water. They do not include factors for obsolescence, installation, maintenance, labor. The estimates have been based on the following unit costs:

Power — 1¢ per kw-hr.
Natural gas — 50¢ per 1000 cu.ft.
Water — 5¢ per 1000 gal.
Ammonia, tank car lots — 4¢ per lb.
Ammonia, cylinder lots — 17¢ per lb.
Carbon dioxide, dry ice — 4¢ per lb.
Carbon dioxide, liquid — 8¢ per lb.

‡Endothermic reaction.

sulphide, and traces of nitrogen oxides. This gives extremely pure nitrogen. So that the unit can be operated continuously, there are three towers. As Fig. 1 shows, air and gas are burned, and pass into the absorption tower where impurities are removed. Meanwhile, another tower is being heated to reactivate the sieve while the third tower is cooling. Each tower absorbs impurities in turn. Once the generator is started, operation is automatically controlled by a timer and electrically operated valves. Units are now operating successfully at Glidden Co., Pratt and Whitney Aircraft Div., and Chevrolet's Aluminum Foundry. The latter company blankets molten aluminum baths with nitrogen to prevent oxidation.

Other companies are also using molecular sieves to dry gas for certain heat treating operations. For example, stainless steels, particularly those alloys containing titanium and aluminum, require extremely dry hydrogen (dew point, −80 to −100° F.) for bright brazing and heat treatment. A unit for this purpose is now operating at Solar Aircraft Co. Installed by Pacific Scientific Co., the equipment is in continuous operation and is fully automatic with built-in fail-safe features. Other units using molecular sieves have been installed by Harper Electric Furnace Co. One, located at Fabriform Metal Products, Inc., Los Angeles, is reported to operate as high as 2500° F. Dew points go down to −90° F., gas consumption is low, and the operation is economical. C. I. Hayes, Inc., is another furnace company that uses molecular sieves for removing impurities from atmospheres.

One point to remember in connection with molecular sieves is that they require reactivation temperatures up to 600° F. Since drying units must be designed with this in mind, molecular sieves cannot replace activated alumina now being used in most standard equipment. Alumina is generally reactivated at 400° F. max.; molecular sieves with this degree of reactivation dry no better than alumina.

Vacuum as an Atmosphere

Many heat treaters class "vacuum" as a protective atmosphere because, obviously, any material treated in a vacuum cannot be contaminated by a gas, *any* gas. Furthermore, the cost for pumps which will do an efficient job of evacuation may be considerably less than the cost of a protective atmosphere. Other advantages of vacuum include the outgassing which occurs (this can improve physical properties particularly in thin strip), and the complete elimination of the explosion hazard.

There are disadvantages, of course. Heat transfer by convection is impossible; thus, vacuum is useful only where rapid cooling (as in quenching) is not needed. One way to get around this drawback is to force-circulate protective atmospheres for rapid cooling.

Some companies are purging furnaces with vacuum pumps. One such unit, a West Coast

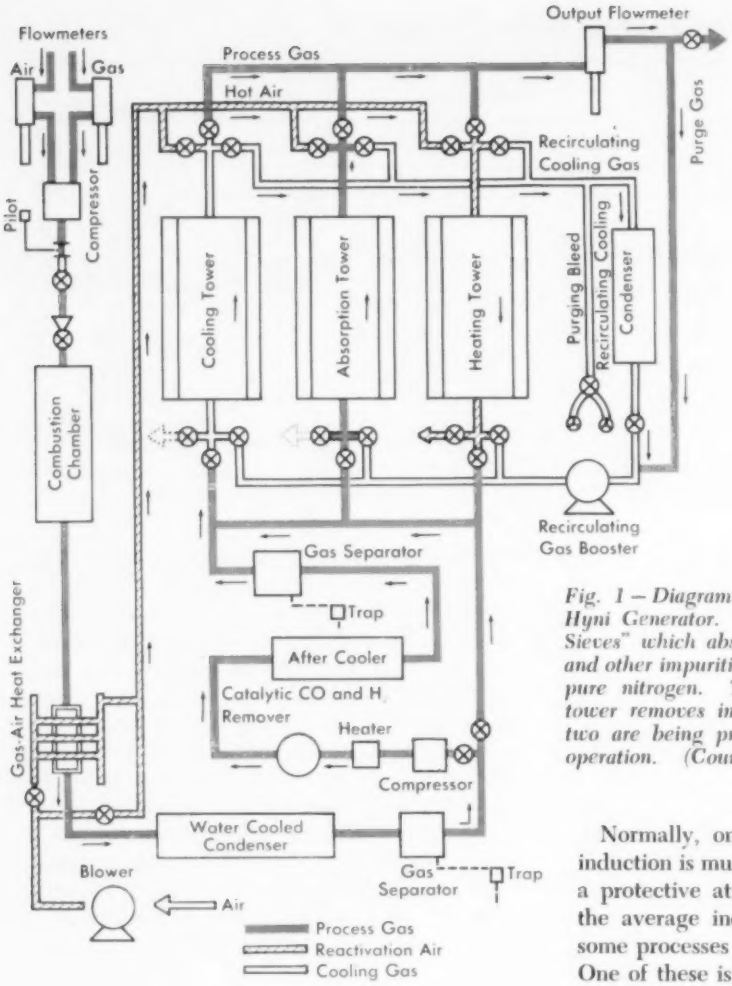


Fig. 1 – Diagram Showing Flow of Gas Through Hyni Generator. Each tower contains "Molecular Sieves" which absorb water vapor, carbon dioxide, and other impurities; this produces an extremely dry, pure nitrogen. Through automatic control, each tower removes impurities in turn while the other two are being prepared. This insures continuous operation. (Courtesy Lindberg Engineering Co.)

installation, provides dry hydrogen for brazing. Prior to admitting the gas, the retorts are exhausted by a vacuum pump. Reducing, or inert, gas is admitted to the retort after an extremely short purging cycle. The retort is pumped out again and refilled; in this manner, rapid cyclic purging is accomplished. Extremely low dew points are obtainable in a few seconds, according to the manufacturers.

Vacuum "atmospheres" are being considered quite extensively to bright anneal stainless steel strip, a material very sensitive to most gases. As reported in *Metal Progress*, July 1959, p. 111, Electric Furnace Co. has been operating such a furnace experimentally for two years, and has interested several steel producers in the installation. According to them, installation costs are higher than those for conventional furnaces, but operating costs are considerably lower.

Normally, one would think that heating by induction is much too rapid an operation to need a protective atmosphere. This is still true for the average induction heating application, but some processes seem to demand an atmosphere. One of these is fluxless brazing. A unit used in assembling Klystron tubes is shown in Fig. 2. Built by Lepel High Frequency Laboratories for Sperry Gyroscope Co., these bell jars enclose Klystrons which are partially assembled. Joints between heavy sections have already been furnace brazed; the joints remaining to be closed are critical, and require that heat be localized. For these joints, silver preforms are positioned during assembly. These preforms are melted by induction heating in hydrogen (or hydrogen plus nitrogen) atmosphere. Since the reducing atmosphere removes oxides from the work during heating, a flux is not needed. Cracked ammonia from a central dissociator is used as an atmosphere.

Atmospheres are used on other induction heating applications. In the article "Improvements in Induction Heating" (*Metal Progress*, February 1959, p. 66), an installation for butt welding tubes is described. A small box is split so that it can enclose the weld zone. Atmospheres are

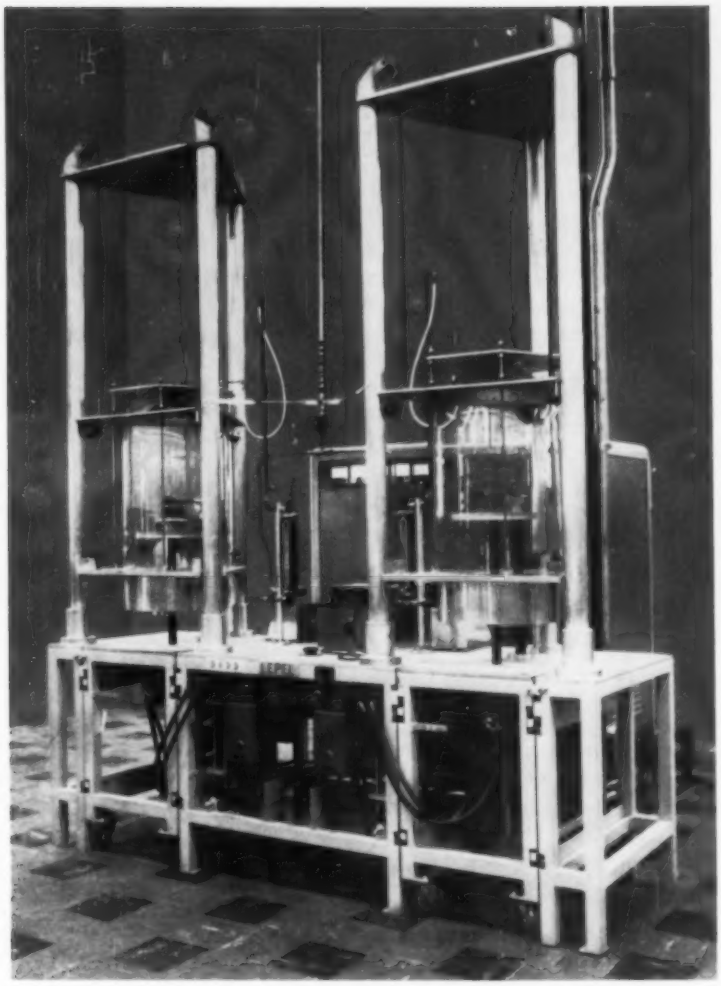


Fig. 2 – These Bell Jars Enclose Klystron Tubes Which Are to Be Brazed in Hydrogen. After tubes are enveloped in the gas, joints are induction heated to melt the brazing alloy. No flux is needed because hydrogen reduces the oxides. (Courtesy Lepel High Frequency Laboratories, Inc.)

circulated through the closed box when scale is expected to affect the weld. This article also mentioned the use of atmospheres in copper-brazing aircraft parts. Controlled atmospheres have been successfully applied to an induction heating machine in an automobile manufacturer's forge plant. To prevent scale formation, forging blanks are heated in an exothermic atmosphere.

Other Developments

The use of by-product nitrogen looms big in the field of controlled atmospheres. In 1958, the steel industry used 28.8 billion cu.ft. of oxygen. Since air, from which this oxygen is distilled, is about 80% nitrogen and inert gases, about 115 billion cu.ft. of neutral gas is available for an atmosphere. At the present time, most of this is going to waste because the nitrogen is contaminated with about 10% oxygen. Thus, the problem is to remove the oxygen. Fortunately, hydrogen does the job efficiently.

According to O. E. Cullen, Surface Combustion Corp., when hydrogen is added to byproduct nitrogen and the mixture heated to combustible temperature (or passed over conversion catalyst at relatively low temperatures), the hydrogen and oxygen form water vapor. This may be removed by condensation in a cooling system or by adsorption in a desiccant to any desired degree of dryness. Any hydrogen unreacted with oxygen will remain in the nitrogen atmosphere to provide reducing properties.

One very common source of supply for hydrogen is the dissociated ammonia generator which thermally and catalytically cracks anhydrous ammonia to a gas containing 75% H_2 and 25% N_2. Recently, a large steel company installed a series of such generators to purify byproduct nitrogen.

Other sources for hydrogen are electrolytic hydrogen cell banks and hydrogen gas generators. The latter crack hydrocarbon gases to produce hydrogen with carbon and oxygen-bearing constituents. The impurities are removed by special processing. The hydrogen generator is expected ultimately to provide the most economical method for purifying byproduct nitrogen.

Some generator builders are doing interesting things to exothermic generators so that they can supply a gas with a range of dew points. As E. C. Buckingham, Pacific Scientific Co., describes it, "As you know, when operating a nitrogen generator at about 7 to 1 air-gas ratio, it is possible to obtain as much as 20% combustibles in the effluent gases." After passing through a refrigerant drier (where the dew point is reduced to 40° F.), this gas goes to a desiccant drier which lowers the dew point to –40 to –60° F. In the furnace, it is normally difficult to control the air-gas reactions of this high-combustible low-dew-point gas. Therefore, a bypass with a flow meter is run from the refrigerant drier past the desiccant drier to the furnace. This enables moist (40° F.) gas to be mixed with the dry gas, thus permitting a range of dew points between 40 and –40° F. in the furnace chamber.

Many heat treaters are finding steam atmospheres quite useful, according to Leeds & Northrup engineers. Steam puts a thin film (less than 0.0001 in.) of Fe_3O_4 on a steel surface. This hard and porous film will resist corrosion and retain cutting oils; both effects help prolong life of cutting tools. Steam also increases hardness and strength of powdered iron parts, adds corrosion resistance and seals microscopic porosity in gray iron castings, and produces a scale-free surface on nonferrous parts.

Operation of a steam unit is fairly easy. The furnace is merely brought to 700° F. and held for 30 min. while being purged with steam. Then the load is treated at the specified time and temperature as steam flows through the furnace. Parts can be air cooled, water quenched, or oil quenched. Though specially designed for steam treatment up to 1250° F., the furnace can also be used with natural or inert atmosphere.

Endothermic Atmospheres and Powder Metals

Powdered iron compacts are much more difficult to heat treat than solid parts because their porosity makes them much more susceptible to decarburization. Consequently, atmospheres are essential for sintering or subsequent heat treatment. Carbon is often controlled during the sintering operation by processing in endothermic atmospheres. Though control of these atmospheres is the same as in the heat treating field, sampling is more difficult because the furnace atmosphere is contaminated by carbon, zinc, or other impurities from lubricants and binders. Consequently, enough atmosphere must flow through the furnace chamber to keep the sintering zone purged.

Where low dew points are needed at high temperatures, materials for muffle construction are limited. To eliminate the need for a muffle, alumina bricks are now being used for furnace linings. Alumina is not reduced by hydrogen until dew points of –150 to –160° F. are reached at temperatures above 2500° F. Elimination of a metallic muffle permits operation at higher temperatures and greater heating rates. Maintenance and downtime are reduced. Ipsen Industries, Inc., reports that it is readying a light and porous brick of alumina which will be usable up to 3400° F. The company expects to use it in furnaces for high-temperature carburizing.

II—What's New in Atmosphere Controls

The main item to note concerning atmosphere controls is that they continue to get more and more complex. Furnace control is becoming automatic, both to minimize operator error (which can occur more easily with manual control) and to improve the product (by insuring a constant proper atmosphere). All builders of atmosphere generators strive to make their equipment simple to operate and accident-proof, but they admit that possibilities for explosions always exist in equipment which generates or uses flammable gases. For this reason, practically all modern generators and furnaces include fail-safe automatic devices. A couple of typical examples will show what we mean.

In an eastern plant which makes automotive parts, Harper Electric Furnace Corp. has installed a furnace for brazing in dry hydrogen, a

Fig. 3 – Control Panel of Unit Supplying Atmospheres for Fluxless Brazing. The panel contains instruments calibrated for hydrogen and nitrogen, and an oxygen analyzer with a dual range. Safety features permit brazing in hydrogen or argon; if neither operation is possible, nitrogen is automatically introduced to allow fail-safe shutdown. (Courtesy Solar Aircraft Co.)

particularly dangerous atmosphere. If the hydrogen pressure or power supply fails, a solenoid shutoff valve automatically cuts off the hydrogen line, starts the nitrogen flow, and sounds a horn alarm.

Elaborate safety equipment is also used in the Solar Aircraft installation mentioned before. The unit automatically records specific gravity of the gas in the retorts as they are being purged with nitrogen. When pure nitrogen is indicated by the meters, hydrogen can be introduced. At this time, the oxygen analyzer is operating. If any oxygen is indicated (this can show a leak), hydrogen flow can be increased. In this manner, oxygen may be reduced to satisfactory limits.

However, if leaks in the retort or supply lines are large enough to make this impossible, the oxygen analyzer warns of trouble by both horn and light. The operator can again try to compensate by raising hydrogen flow. If this doesn't work, argon is automatically introduced to purge the system. Thus, a safe atmosphere is maintained, and brazing can continue. If the argon supply is exhausted, nitrogen is automatically bypassed through the system, and a fail-safe condition is produced. This system satisfies safety requirements, and also protects parts being processed. As illustrated by Fig. 3, the setup consists of a panel with Ranarex instruments calibrated for hydrogen and nitrogen, and an A. O. Beckman oxygen analyzer.

Another trend in controls that is appearing concerns continuous gas analysis. In many areas of the country, natural gas supplied by local fuel companies varies in chemical analysis, particularly during the winter months and off-peak hours. Why? This gas comes from many fields throughout North America. From time to time, these various fields will be cut in or out of the main distribution system. The cold of winter increases the demand, and the natural gas must sometimes be supplemented with propane or other manufactured gas. Since gas companies prefer to maintain consistent Btu. values, analyses often suffer. The table shows how analysis varied on different days in one large Midwestern city:

	Gas No. 1	Gas No. 2
CO_2	0.8%	0.5%
O_2	0.6	0.9
CH_4	78.7	85.9
C_2H_6	11.6	4.2
C_3H_8	0.0	1.7
C_4H_{10}	0.0	0.3
C_5H_{12}	0.0	0.1
N_2	8.3	6.4
Specific gravity	0.636	0.653

Though both gases are equal in heat content

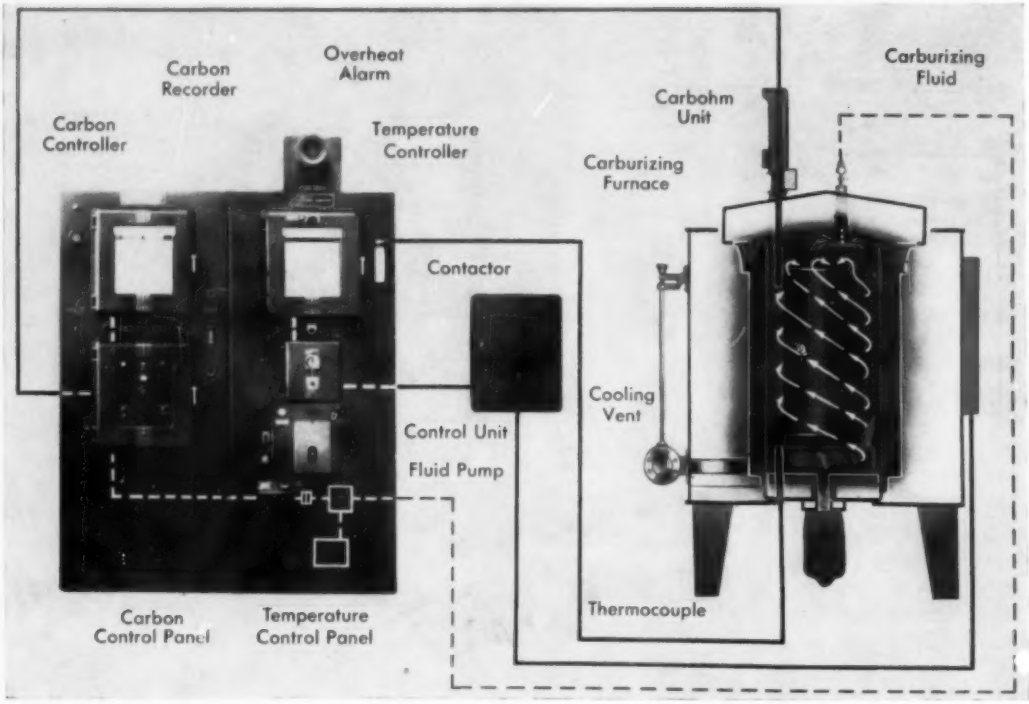


Fig. 4 – Furnace for Accurate Control of Surface Carbon. Flow of "carburizing fluid" is increased or decreased in accordance with signals fed back from Carbohm unit. For good results, work must be thoroughly cleaned before being placed in the furnace chamber. (Courtesy Leeds & Northrup Co.)

(1004 Btu.), such a variation in analysis could cause an appreciable change in generator gas output. The gas cracking process is chemical in nature; if the raw gas analysis changes without proper compensation of the air-gas ratio, the dew point will also change. Not only that, but the catalyst can become ruined if the generator is operating with too rich a mixture. Such an event can be quite costly and waste hours of production time.

To avoid this, many plants apply continuous control to the output of their generators. Devices can be installed to determine the dew point or analyze the output continuously. When the gas gets out of control, the information is fed back to the input. Valves controlling the air and gas inputs then go into action to alter the gas flow so that the correct atmosphere is again emitted. If the correct gas analysis is continually maintained, losses from downtime and ruined product can often be held to a minimum.

Various Types of Controls

Control panels for atmosphere generators may include devices for measuring dew points, amounts of oxygen and combustibles, temperatures, pressures and other variables. Basically, all of these items have one purpose: to monitor the atmosphere so that it is always able to do the job it is meant to do. These controls take many forms. For example, dew point alone can be measured in several ways. According to users, one dependable unit is Foxboro's Dewcel, the operation of which is based on the hygroscopic properties of lithium chloride. Manufacturers other than Foxboro – Lindberg Engineering Co. and Surface Combustion Corp. are two examples – use the cell in their dew-point control instruments.

Another type of dew-point controller is marketed by Surface Combustion Corp. The gas being tested is directed onto a metal mirror cooled by refrigeration. When it fogs, the temperature is measured by a thermocouple firmly attached to the mirror. Through proper cycling and electronic instrumentation, dew point is continuously recorded or controlled.

The Dewtronik, Ipsen Industries' contribution to dew-point control, is a simple device. The atmosphere to be sampled is continuously pumped over two platinum electrodes separated by a

small gap. When cooled to the dew-point temperature, moisture condenses between the electrodes. This reduces the electrical resistance between them, and energizes a heating element in the head. After the moisture is driven off (by the heat), the cycle is repeated. The information is fed to a potentiometer and then recorded as a temperature.

For carbon control, the furnace temperature is also determined. It is combined electronically with the dew-point temperature for automatic computation in a special potentiometer calibrated in percent carbon.

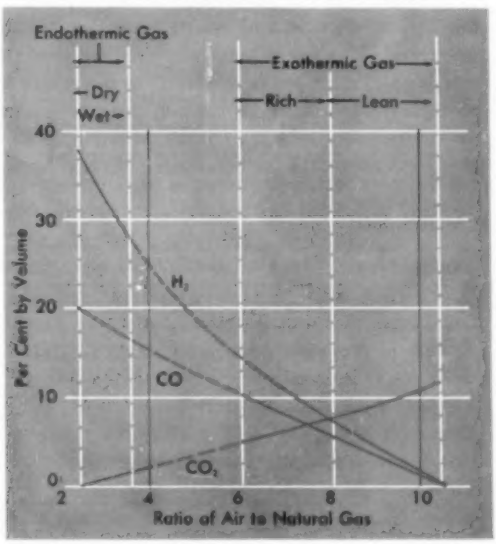
A new dew-point indicator is being developed by one of the country's leading instrument makers. Based on the wet bulb principle, it is designed to measure dew points (between –20 and 60° F.) of air and noncorrosive gases. Continuous measurement is achieved by passing a continuous flow of gas through the device. The unit has a high-speed response, is compact, and has no moving parts. According to two generator manufacturers, Hevi-Duty Electric Co. and Pacific Scientific Co., this has much promise.

Most manufacturers of atmosphere generators use dew-point controls because they offer a convenient and simple method for determining carbon potential. Another method, which is based on an entirely different principle, is the "Carbohm" offered by Leeds & Northrup Co. The heart of this device, which is actually part of a complete furnace setup, as Fig. 4 shows, is an iron-nickel wire that responds to the carbon potential as the steel is being treated. Being fine, the wire rapidly reaches equilibrium with active carbon in the atmosphere. As the carbon content in the wire varies, its electrical resistance changes. This change is measured on a Wheatstone bridge, and carbon percentage is read directly on the instrument scale. The "Carbohm" controls the addition of a liquid hydrocarbon which is decomposed by the furnace heat to supply the carburizing atmosphere.

Another device for continuous gas analysis is the infrared analyzer marketed by Leeds & Northrup. The method of measurement, though unique, is simple. To be brief, different gas compounds in a mixture absorb radiation from different parts of the infrared spectrum. When infrared radiation is passed through the sample to be measured, and, at the same time, through a known reference gas, the difference in radiated energy between the two is detected by a thermopile. These changes are fed to a recorder or controller which is calibrated in percent of the gas component being measured (it can be CO or CH_4, for example). Calibration is easily done in about 3 min. by using a gas with a known concentration of the constituent being measured.

Space is too limited to include descriptions and discussions of all the control equipment that is available. Let it be said only that there are probably devices already in existence that will fill any need. Where gaps are present, the imagination of the instrument maker will surely close them in a short time.

Fig. 5 — Endothermic and Exothermic Gas Constituents. Nitrogen is not included; it is the remainder at various ratios



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III—Choosing the Right Atmosphere

*By L. L. PATTON**

GENERALLY, THE PURPOSE of a protective atmosphere is to prevent, to minimize, or to control surface changes of work being heat treated. While the basic premise is simple, the many types of atmospheres available complicate the problem of selecting the right atmosphere for a specific application. Engineers must consider, among other items, such factors as type of gas, cost and type of heat treatment, and material being treated. Characteristics of common atmospheres and some of the rules for their selection are given in this article.

The most common protective atmospheres are obtained from the products of combustion of hydrocarbon fuel gases. Exothermic gas is obtained over the range of air-to-gas ratios that will support combustion. The reference "lean" (or "rich") pertains to the combustible content which consists primarily of hydrogen and carbon monoxide. Complete combustion, which needs about a 10 to 1 air-to-natural gas ratio, produces the leanest (inert) gas. Conversely, the richest (most reducing) gas is obtained at 6 to 1 air-to-gas ratio. At the latter ratio there is about 1% methane which drops to zero when the ratio rises to between 6½ and 7. Both rich and lean exothermic gases are saturated at about 10° F. above cooling water temperature.

Both carbon dioxide and water vapor can be removed from exothermic gas, leaving only hydrogen, carbon monoxide and nitrogen; this gas is called "purified exothermic gas". If carbon monoxide is also removed, the gas is called "CO-free purified exothermic gas".

In the endothermic gas range, the air-to-gas ratio is too rich to support combustion and the reaction takes place in an externally heated retort. The terms "wet" and "dry" refer to the moisture content of the endothermic gas as it leaves the gas producer. Within practical operating ranges the moisture content can be varied by "air-gas" ratio adjustment without the use of auxiliary drying equipment.

Table I (p. 147) summarizes the composition, dew point, and cost of the various types of atmosphere gases. Information of this sort is useful when considering applications for protective atmospheres because the composition of the various gases indicates the degree of reactions that are available.

Pure hydrogen is the most reducing of all gases, but its high cost limits its use to those applications where no other gas is satisfactory. A mixture of 75% H_2 and 25% N_2, obtained by dissociating ammonia, is often a good substitute for hydrogen and is much lower in cost.

Rich exothermic gas is the cheapest gas that can be obtained, and is normally used for most heat treatments of low-carbon steels. Even though this gas may be saturated with water at 95° F. and contains about 5% carbon dioxide, there is enough hydrogen and carbon monoxide for the gas to be reducing. At lean ratios, this gas is oxidizing to ferrous metals but is satisfactory for use with nonferrous metals.

Purified exothermic gas at the rich ratio has about the same carbon monoxide and hydrogen content as does rich exothermic gas. However, the carbon dioxide and water vapor have been removed. This gas is generally used for medium and high-carbon steels where it is necessary to prevent decarburization. When the gas generator is operated at a lean ratio (about 9.25 to 1 air-to-gas ratio), the carbon monoxide and hydro-

*Industrial Heating Dept., General Electric Co., Shelbyville, Ind.

Table II — Typical Atmosphere Applications

Atmosphere	Copper and Brass			Stainless Steel	Low-Carbon Steel			Medium and High-Carbon Steel			
	Anneal	Braze	Sinter		Anneal	Braze	Sinter	Anneal	Harden	Braze	Sinter
Dissociated ammonia				X*	X	X	X				
Exothermic gas	X	X	X		X	X	X				
Purified exothermic gas (with CO)	X							X	X	X	X
Purified exothermic gas (CO-free)	X				X	X	X				
Endothermic gas						X	X	X	X	X	X

*Braze, harden and sinter.

gen are decreased; however, the gas is still dry and free from carbon dioxide. Because of the low combustible content, this gas is nonexplosive. If carbon monoxide is removed, the combustible content remains unchanged because the carbon monoxide is replaced with a like amount of hydrogen.

When the generator is operated at lean ratio, purified exothermic gas often substitutes for bottled nitrogen. In fact, this gas has an advantage as a furnace atmosphere over bottled nitrogen because it is produced with a slight amount of carbon monoxide and hydrogen which will counteract oxygen infiltration. Bottled nitrogen has no combustible content, and the oxygen must be eliminated or counteracted by diffusion and increased rates of flow.

Endothermic gas, operated on 2.4 to 1 air-to-gas ratio, has considerably higher hydrogen and carbon monoxide than can be obtained with the other types of gases. The dew-point range may be as low as 0° F. at the generator. When considering heat treatments of medium and high-carbon steel, such endothermic gas is interchangeable with purified rich exothermic gas.

Table II gives applications for various protective atmospheres. Dissociated ammonia is used mainly when stainless steels are to be brazed, hardened, or sintered. Though it can be used for low-carbon steels, it is generally not used for medium and high-carbon steels. This is because dissociated ammonia has no carbon potential to offset the decarburizing effects of water vapor which is present in most furnace atmospheres.

Dissociated ammonia is not recommended where nitriding by molecular nitrogen is undesirable. Thus, dissociated ammonia is not recommended for sintering stainless steel powders containing small amounts of titanium or columbium, or for sintering molybdenum powder.

Exothermic gas is widely used for nonferrous metals, particularly copper and brass, for annealing, brazing, and sintering. It is also used for low-carbon steels. Bronze, silver, and iron are also sintered in exothermic gas. One precaution: Sulphur, if present, must be removed from exothermic gas used for nonferrous parts.

Purified exothermic gas is generally used for medium and high-carbon steels because of its high carbon potential. This gas, when at a lean ratio, is also used for annealing of copper and brass. Purified exothermic gas, considered to be mildly reactive and quite stable, is used when sintering iron and iron-graphite parts. Some users sinter both iron and iron-graphite parts in the same gas without noticeable carburizing or decarburizing. Users consider this gas to be neutral, and no attempt is made to change the atmosphere other than to keep it dry and free from carbon dioxide. Purified exothermic gas, which contains no carbon monoxide or carbon dioxide, is used for heat treatments of low-carbon steel, particularly for annealing steel strip before galvanizing or tin plating.

Dry endothermic gas, which is highly reactive, is normally used for treating medium and high-carbon steels. Generally, the air-to-gas ratio is adjusted for a particular dew point to match the carbon content of the work being heat treated.

Wet endothermic gas is satisfactory for low-carbon steels. However, our experience has been that the endothermic gas producer is normally used with medium and high-carbon steels, and is rarely operated in the wet range. Obviously, if you were heat treating only low-carbon steel, you would consider rich exothermic gas in preference to the wet endothermic gas. Not only is the atmosphere itself cheaper, but the gas-producing equipment for the exothermic gas costs less than that required for endothermic.

General Considerations

Table II shows that there is no all-purpose protective atmosphere – that is, no one atmosphere that will be suitable for all heat treatments. When considering an individual application, it is generally fairly easy to obtain the particular type of atmosphere that will give the desired results. For example, if you heat only low-carbon steel, a rich exothermic atmosphere is all that is necessary. This is not only the cheapest gas available, but it also requires the cheapest gas producer equipment.

On the other hand, if you are considering an atmosphere for heat treatment of medium and high-carbon steel, then there are two types to be considered – purified exothermic and endothermic. Even though purified exothermic gas is about 20% cheaper than endothermic (when considering only the materials consumed), there are other factors that must be taken into account.

The initial cost difference between two types of gas producers will vary at different output ratings. For instance, if the requirements are for an output under 6000 cu.ft. per hr., the endothermic gas installation may be cheaper. Conversely, for greater outputs, the purified exothermic gas installation will cost less. This is be-

Atmospheres in Missile Heat Treatment

*By N. K. KOEBEL**

TODAY'S AND TOMORROW'S intercontinental missiles present a difficult heat treating problem. Every pound of steel that can be eliminated from the motor case means an additional pound of fuel. Because of this, the wall thickness of the long-range missile is now about 0.085 to 0.125 in. and is approaching 0.065 in. Furthermore, as walls get thinner, diameters and lengths grow. Thinner walls, larger sizes, and more stringent specifications all combine to make the heat treatment of missile cases a tough problem.

To meet these stiffer standards, the engineer has turned to alloy steels and reduced the design factor of safety far below the percentage factor normally used. This means the heat treatment of the steel from the point of view of decarburization, carburization, autenitizing temperature, speed of quench, and tempering must be perfect. The furnace atmosphere must be controlled to eliminate total decarburization and hold partial decarburization to under 0.003 in. Equally important, partial carburization must be held under 0.003 in.

The Case Holds Much Air

How can the furnace engineer meet such specifications? Let's take a look at the Minuteman — one of the country's newest missiles — and see what problems it presents. It is about 6 ft. in diameter and about 22 ft. long. While one end is fully opened, the other end is nosed down to about a 7-in. diameter area. Thus, this case contains some 500 cu.ft. of air. This large volume must be dealt with if contamination is to be avoided.

What must be done to keep the atmosphere in perfect equilibrium with the steel? The first possible solution is to purge the furnace (after loading the missile motor case) to expel the contaminated atmosphere before the steel can reach a decarburizing temperature. With considerable past experience in designing large bottom-quench gantry furnaces, Lindberg engineers decided this would not be the solution. They felt that the infiltration problem was so great that it would not be practical to supply the quantity of atmosphere required to purge the furnace in the time required. Too large a generator and atmosphere storage would be required, and too much heat would be lost from the furnace. Also it would be difficult to introduce and vent off the large volume of gas which would be needed.

The second possible solution was to use the normal flow of atmosphere. Natural gas added at the beginning of the cycle could remove the oxygen. This has been done on smaller furnaces, but again we felt that the infiltration factor was too great. If the reaction between gas and oxygen were not complete, decarburization could occur at one end of the furnace while carburization occurred at the other end.

*Manager, Heat Treating Furnace Div., Lindberg Engineering Co., Chicago.

cause the purified exothermic gas producer lends itself readily for large-capacity outputs from a single combustion chamber.

On the other hand, the endothermic gas producer has a limit as to the retort size with respect both to the quality of gas produced and the cost of the retort. Consequently, installations for larger capacities of endothermic gas consist of multiple units whereas the purified exothermic installation can consist of only a larger single unit. Generally, the purified exothermic gas producer is desirable for installations that require several types of gas coming from the same gas producer. It is possible to bypass the purifying equipment so that unpurified exothermic gas can be used. Also, the drying equipment can be bypassed, and the carbon potential controlled inside the furnace by mixing wet and dry gas. Thus, the installation is quite versatile.

Even though the equipment required for the purified exothermic gas producer may be more complex than that required for endothermic gas, a trained operator can run either gas producer with equal skill. In fact, the purified exothermic gas producer actually requires less attention than is needed for the endothermic gas producer. This is particularly true in areas where the analysis of the fuel gas is constantly changing.

The third possible solution was to eliminate infiltration by purging the air from the missile before putting it in the furnace. We considered this the only foolproof method available.

Lindberg engineers designed a combination loading-purge and atmosphere quench chamber. The chamber was placed in the pit below the gantry furnace, and was complete with gastight doors. Water jackets and recirculating fans were used for the quench cycle.

In operation, the missile is placed in the purge chamber and the gastight door is closed. Nitrogen is introduced to purge the air from the missile body. After instruments show that the percentage of oxygen in the effluent gas from the purge chamber approaches zero, the gantry furnace is moved over the purge chamber. A turtle-neck device seals the gantry furnace to the purge tank. Then, the doors on the purge tank and the heat treating furnace open, and the missile case is pulled up into the furnace. No air from the room enters the furnace chamber. When heating is complete, the case is quenched in an atmosphere.

Nitrogen was chosen for the purge and quench because of its safety advantages. For the heat treatment, endothermic atmosphere was selected; past experience has proven it to be the most flexible to adjust and control for carbon potential.

To obtain complete automatic control, both the endothermic generator and the furnace chamber are independently controlled. The generator control is set to give a dew point of about 15° F. lower than necessary for the steel to be treated. To achieve the exact dew point, the furnace is set to the dew point required for the steel at the temperature of treatment. The instrument adds a small amount of air to the endothermic generator gas so as to react at furnace temperature to give the desired dew point.

Installation of the described furnace in an associate organization (Lindberg Steel Treating Co.) gave us a wonderful opportunity to test the three control methods discussed above. A "dummy" missile case was used. Method No. 1, using a large flow of endothermic atmosphere to purge the missile body after loading into the furnace, proved that decarburization could not be overcome by doubling the normal atmosphere flow. Furthermore, the increased flow of atmosphere slowed heating of the missile cases, and the heating rate from zone to zone was not as uniform. (To control distortion, the missile must be heated evenly throughout its length.)

Method No. 2, enriching normal atmosphere with natural gas to overcome the high dew point imposed by loading a missile full of air into the furnace, showed that carburization would occur on certain sections along the missile case, while decarburization occurred simultaneously on other sections. Though the dew-point control chart showed good recovery, nascent carbon from the gas evidently caused localized carburization.

Method No. 3, purging all air from the missile with nitrogen before loading and quenching the missile without contact to air, gave perfect control over both decarburization and carburization.

This program illustrates the importance of over-all furnace design in achieving full control of a furnace atmosphere. A control instrument alone cannot do a control job if the entire process is not designed to be controlled. A point to remember: If a furnace cannot be controlled manually, it cannot be controlled automatically. Conversely, once manual control is achieved, automatic control requires little further work.

The actual cost of atmosphere gas for most heat treating applications is relatively small compared to the total cost going into the finished product. Also, the cost of gas-producing equipment is relatively low when compared to the cost of the other heat treating equipment that is required.

The operation of gas producing equipment is comparatively trouble-free and simple. Raw materials for the most part consist of hydrocarbon fuel gases which are readily obtainable. Maximum control of an individual process is much easier when the atmosphere is obtained from a generator supplying only that process.

One of the basic reasons for the wide application for various heat treatments has been the ability to obtain atmospheres which can control metal surfaces during the process. Because of this, development of gas-producing equipment closely parallels the development of various types of furnaces. The best controlled atmosphere is useless unless it can be satisfactorily applied to the proper heat treating equipment. The successful heat treating process is dependent upon the use of proper equipment under the proper conditions with adequate maintenance and operating practice so that the results can be readily duplicated.

Correspondence

"Unbreakable" Ships in a Hurry?

ZUG, SWITZERLAND

I have just read with great interest the Critical Point entitled as above in *Metal Progress* for April 1959, and the following article in that issue on "Tough Ship Plate", by Messrs. Harris and Williams.

I wish to agree with your editorial attitude that one preventable shipwreck is one too many. I believe it is also the attitude of those who are responsible for the security of welded ships and the lives of the sailors who have to live on them. This is the reason I turned my attention some years ago to the problem of tough versus brittle steels and developed the test which bears my name and which is much more widely used in Europe than in America. In fact by using it steels have been produced with completely crack-arresting ability and at least one ocean-going tanker, the Swedish-built Tank Emperor, made therefrom (1950).

In my opinion, the metallurgy of tomorrow will be based on physics and mathematics. It is time to abandon the purely empirical approach. This will involve many new concepts and terms. Even though they seem strange at first, they do have real meaning. Dealing with the fundamental problems of residual stress, start of brittle fracture and speed of break without physics and mathematics is like dealing with infectuous diseases without knowing that there are microbes.

Perhaps you will be interested in printing the basic formula governing the brittle or plastic behavior of metals, for all kinds of stresses, all straining speeds and practically all temperatures. A monograph deriving this formula has recently been published by the undersigned at 36 Hofstrasse, Zug, Switzerland.

HENRI M. SCHNADT
Engineer
Oerlikon Machine Tool Works

The formula follows:

$$\log \frac{\Pi}{\phi_{ooo}} = a_o\left(1 - \frac{h}{a_o} - \frac{w}{G}\right)\frac{u}{u-10} + b_o w$$

where Π = plastifying power
ϕ_{ooo} = standard endobrittleness
a_o = antithermic constant
h = cotoxy of the metal
w = velogtony
G = endotachy
u = anti-temperature
b_o = velogtonic constant

A Definition of "Metallurgy"

CRANFIELD, BUCKS, ENGLAND

Could I add my contribution to those you will receive from friends (or enemies, if it is conceivable you have any) about the definition of the term metallurgy in "Press Breaks", p. 5, *Metal Progress* for April 1959, which really reads like a summary of the contents of any annual volume of *Metal Progress!* The definition I always use, though I cannot claim any originality, is: "Metallurgy is the art and science of winning metals from their ores and adapting them to the service of man."

I am not sure that *definition* is the real problem; the puzzle, in this country at least, has always been *pronunciation!* For example, at the inaugural meeting of the Institution of Metallurgists, back in September of 1945, the first problem for discussion raised by the president was to decide if the new body should be called the Institution of Me-*tall*'-urgists or the Institution of Me-tall-*ur*'-gists. No decision was taken, but the Institution of *Metallurgists* was duly founded.

JOSIAH W. JONES
Senior Lecturer, Metallurgy
The College of Aeronautics

More on Welded Aluminum Mine Cars

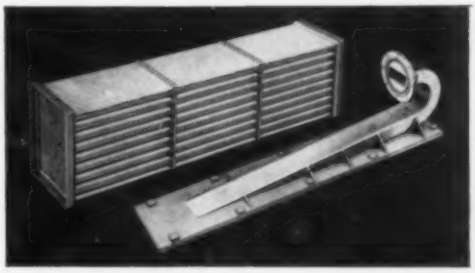
SYDNEY, NOVA SCOTIA

My attention has been drawn to the article "Welded Aluminum Mine Cars", by J. R. Flynn, *Metal Progress*, May 1959, p.114, in which an erroneous statement credits production of the first all-aluminum mine cars in the world to the Watt Car and Wheel Co., Barnesville, Ohio.

I am writing to point out that in 1949 the Dominion Coal Co. in Nova Scotia designed, purchased and put into operation a number of mine cars having all-aluminum bodies. Built for us by the Eastern Car Co. of Trenton, Nova Scotia, these are of riveted construction and have a capacity of 3 tons of coal or approximately 5 tons of rock. The wheels and axles and the coupling link and pin are the only steel on the cars. Even the heavily stressed combined drawhead and bumper is an aluminum casting.

It is perhaps not fair to draw a parallel between the Watt Co.'s 15-ton cars and our 3-ton cars, but the fact that, after 10 years of operation, we are still using this type of car

ALUMINUM COATED STEEL HARDWARE provides exceptional low cost corrosion and high heat resistance. The "heart" of the coating process is a 200 kw Ajax furnace used for preheating and fluxing.



THESE COMPLICATED ALUMINUM ASSEMBLIES are dip brazed in a matter of minutes on a production basis. Finish machining and straightening of brazed assemblies have been virtually eliminated.

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MAGNESIUM BRAZING, TOO!

Interesting to note also, is the fact that several Ajax users are making rapid progress in dip brazing magnesium *commercially.*

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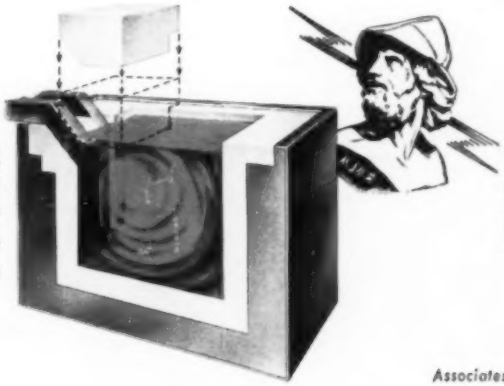

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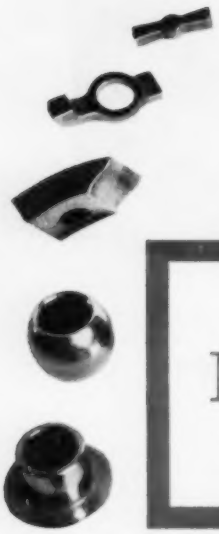

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—and for the controlled physical qualities you demand in the finished part

The improved particle shape now achieved in Vasco Prealloyed Metal Powders results in better moldability and increased green strength . . . advances that join with the inherent superiority of *prealloyed* powder performance to create the most versatile, easy-to-use range of high-strength metal powder grades available today.

Each Vasco Prealloyed powder particle, produced from a molten stream of metal, is a tiny ingot of exactly the same chemical composition as the original melt. Your part made from such a powder is completely homogeneous—as much so, except for density, as a solid bar of the original analysis.

Select Vasco Prealloyed Metal Powders from many grades available, including chrome-nickel stainless, chromium stainless, low alloy structural, nickel and silicon-iron, hard facing alloys and brazing powders, nickel-copper and nickel-chromium iron alloys, special corrosion and heat resistant alloys and tool steels. Your orders are filled promptly from our mill warehouse. Write.

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Vanadium-Alloys Steel Company

Powder Metallurgy Department

LATROBE, PENNSYLVANIA

Correspondence . . .

and in fact extending its usage to other mines is a fair indication that they are more economical in operation than the steel cars which they replaced.

J. A. Russell
Chief Mechanical Engineer
Dominion Coal Company, Ltd.

"Drop Forge" Defined

Erie, Pa.

When I opened my copy of the July 1959 issue of *Metal Progress* and glanced at the fine picture on p. 67, I was surprised to find it described as a "Drop Forge in Action", according to the caption. The machine shown is, of course, a hydraulic press, forging an ingot.

In any event, I do not think it correct to use the word "drop forge" as applying to any machine. I think that dictionaries usually define the noun "forge" as an establishment where metal is heated and forged, or the apparatus in which the blacksmith builds his fire to heat the metal. As applied to an establishment, in modern practice, the term usually implies a blacksmith shop, where the forging is done by hand. Usually, but not always, the word shop is added where the forging is done by machinery and it is thus called a forge shop or drop forge shop.

In trade I do not think that the machine that does the forging is ever referred to as a forge. It is a hammer or a press or an upsetter. The word "forge" is used as a verb, except as indicated above.

Macdonald S. Reed
Vice-President
Erie Foundry Co.

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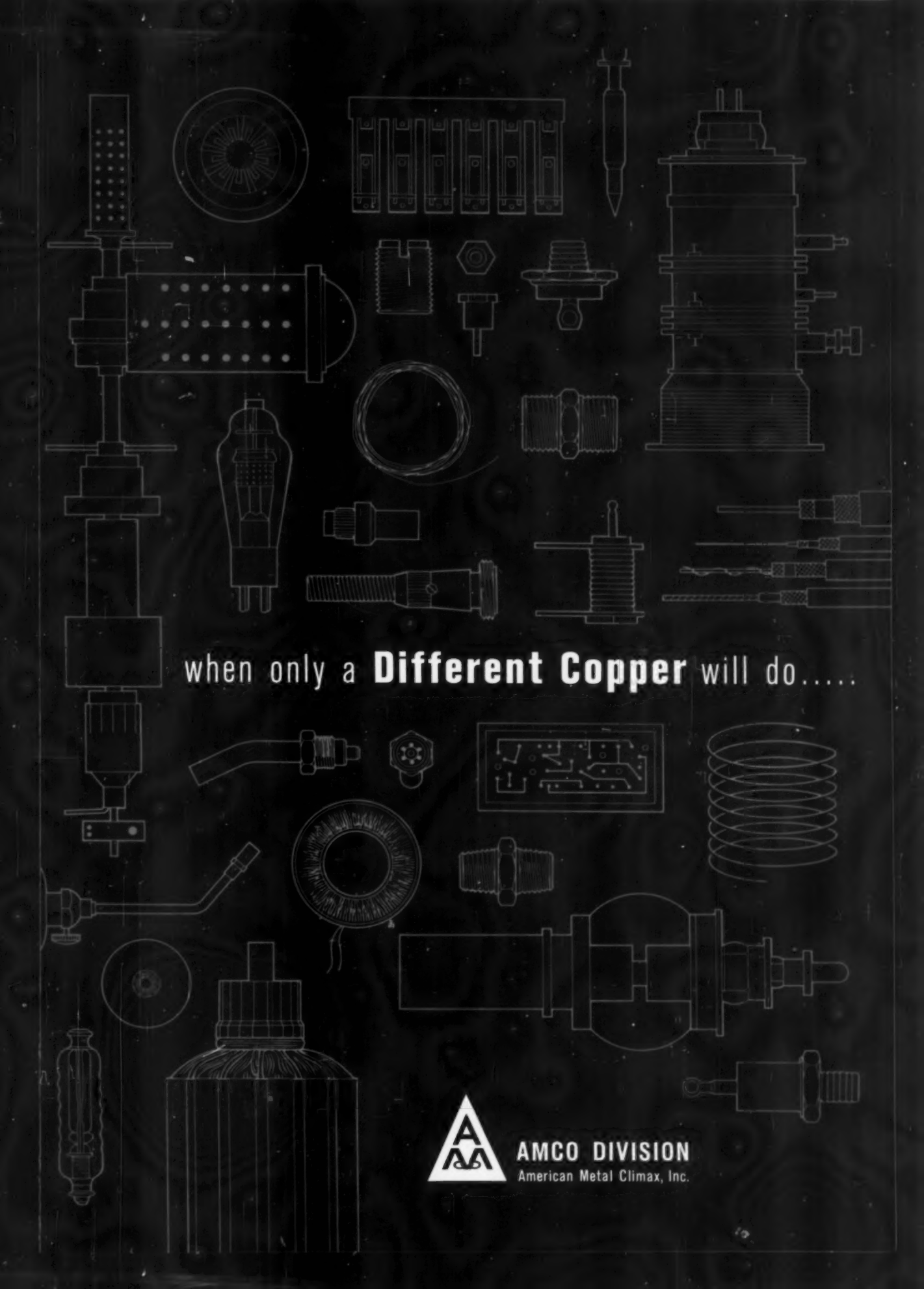
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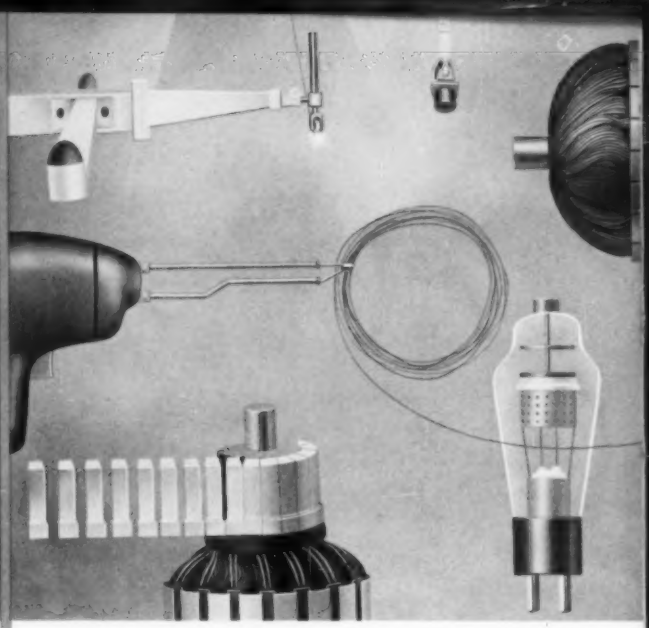
American Metal Climax, Inc.



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DISTINCTIVE CHARACTERISTICS: Totally free of oxides and residual deoxidizers, OFHC is 99.99% pure copper. For more than 20 years it has been recognized as the *one* copper able to meet all demands for precision electronic and electrical applications. OFHC offers high conductivity . . . excellent hot and cold workability . . . immunity to hydrogen embrittlement . . . soundness and high density to assure total vacuum . . . low volatility under high vacuum . . . adherent oxide scale . . . superior anodic action in electroplating.

APPLICATIONS: OFHC is the preferred copper for essential parts of electronic components such as high-frequency oscillators . . . magnetrons . . . triodes . . . tubes requiring glass-to-metal seals. Rotary components of power-generating equipment and other items requiring the highest obtainable electrical and thermal conductivity rely on OFHC.

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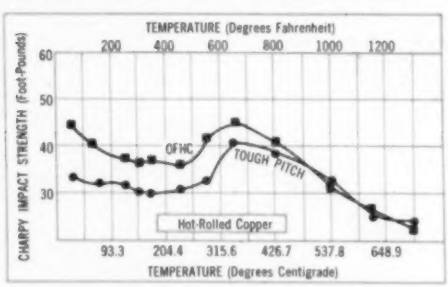

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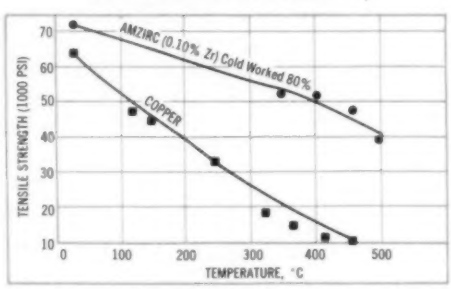
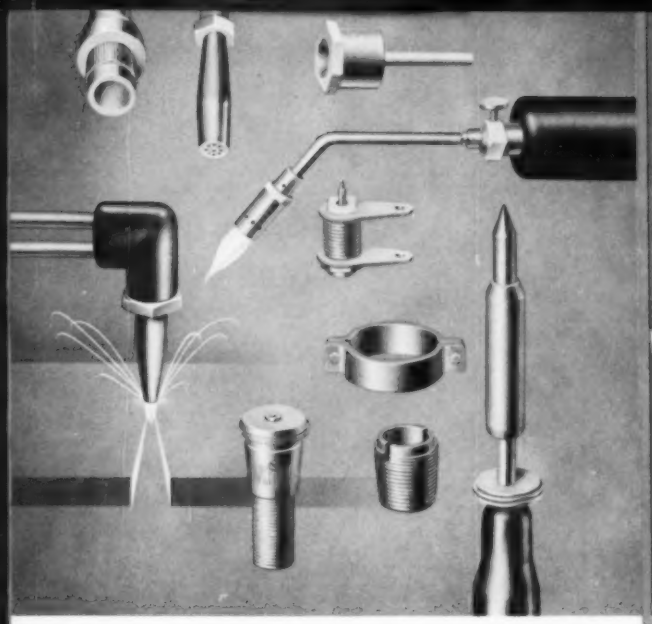
When you need tensile strength of up to 52,000 psi at 400°C plus conductivity of 95% IACS

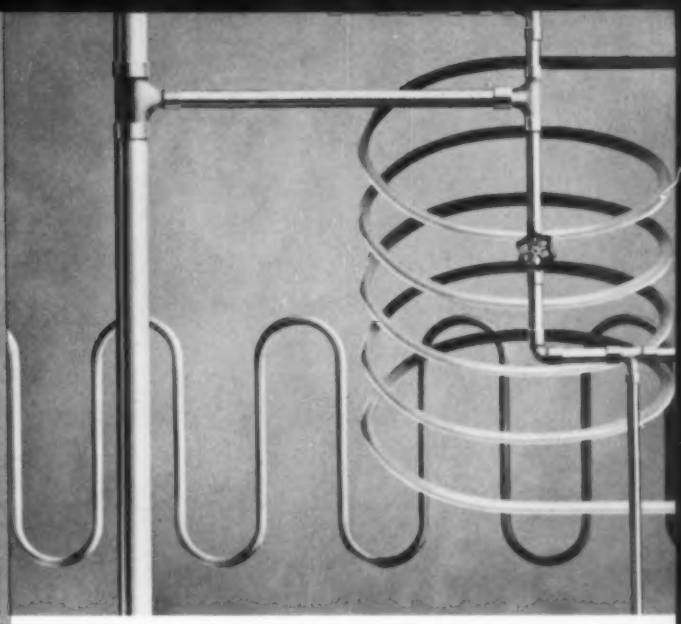
DISTINCTIVE CHARACTERISTICS: AMZIRC consists of OFHC Copper and a rigidly controlled addition of high-purity Zirconium. The designer will find in AMZIRC high conductivity . . . retention of strength at elevated temperatures where copper and conventional high-conductivity alloys weaken . . . extreme notch toughness . . . transverse properties equal to longitudinal properties . . . hardness . . . exceptional hot and cold workability.

APPLICATIONS: Typical of the many products that have been improved or made possible by AMZIRC's unique combination of characteristics are high-temperature magnet wire . . . commutators and collector rings . . . rotor wedges . . . resistance welding wheels and tips . . . electron tube studs and side rods . . . rectifier bases.

TENSILE STRENGTH vs TEMPERATURE







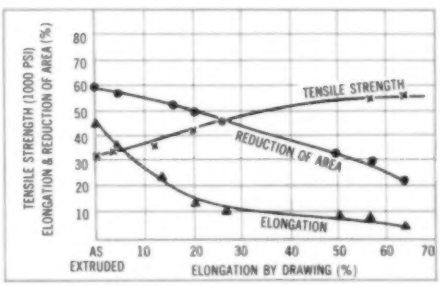
AMSULF®

When you need machinability rating of 90 and good workability, plus conductivity of 96% IACS

DISTINCTIVE CHARACTERISTICS: AMSULF is produced by combining OFHC Copper and a nominal 0.3% sulfur. This alloy provides high conductivity . . . rapid cutting rates . . . short chip formation . . . low power consumption relative to tool bite . . . excellent hot and cold workability . . . freedom from hydrogen embrittlement . . . fine surface finish and corrosion resistance.

APPLICATIONS: AMSULF is ideal for machined parts, especially automatic screw machine products. Its hot and cold workability and immunity to hydrogen embrittlement allow fabricating and finishing techniques impossible with conventional free-cutting coppers. Representative of the parts now being produced from AMSULF are flame-cutting nozzles . . . parts for motors and switches . . . electrical connectors, clamps, and clips . . . soldering iron tips . . . studs and terminals.

RELATIONSHIP OF ELONGATION, REDUCTION OF AREA, AND TENSILE STRENGTH



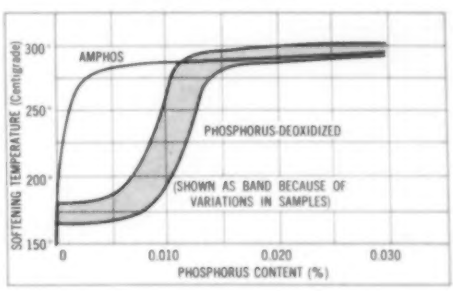
AMPHOS®

When you need exceptional hot and cold workability plus rapid piercing and drawing rates

DISTINCTIVE CHARACTERISTICS: Unlike ordinary phosphorus-*deoxidized* copper, AMPHOS is produced by adding to *oxygen-free* OFHC Copper a rigidly controlled amount of phosphorus. This results in a high-purity copper having uniform distribution of a predetermined phosphorus content. Distinguishing AMPHOS are high density . . . free-scaling properties . . . freedom from hydrogen embrittlement . . . improved cold workability . . . absence of voids . . . high softening temperature.

APPLICATIONS: AMPHOS should be specified for all tube, pipe, and related products where exacting specifications or fabricating techniques result in an appreciable number of rejects when ordinary phosphorized copper is used. Its suitability for welding and brazing and immunity to embrittlement make AMPHOS a superior material for condenser tubes . . . heat exchange units . . . coils . . . complex piping.

SOFTENING TEMPERATURE



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Free Technical Literature on AMCO's Unconventional Coppers

One of AMCO's coppers with unique combinations of characteristics may hold the elusive answer to your design problem. Another may help you hone your product's competitive edge. Starting point in discovering how to put these unusual metals to work for you are these books, booklets, and technical papers. There's no charge or obligation, of course. Also available without cost is metallurgical design service. Just contact the AMCO Technical Service Section.

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- **"TECHNICAL SURVEY OF OFHC COPPER"**
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- **"OFHC...PREMIUM COPPER FOR PRECISION ELECTRONICS"**
  8 pages, Pub C-13
- **"AMZIRC...HIGH-CONDUCTIVITY ALLOY WITH HIGH STRENGTH AT ELEVATED TEMPERATURES"**
  8 pages, Pub C-16
- **"AMSULF...FREE-MACHINING ALLOY WITH HIGH CONDUCTIVITY AND UNIQUE WORKABILITY"**
  8 pages, Pub C-17
- **"AMPHOS"...PHOSPHORIZED COPPER FOR BETTER RESULTS IN TUBE, PIPE, AND ALLIED PRODUCTS"**
  8 pages, Pub C-12

You will find investigation of the other products in the AMCO Copper Line rewarding, too. The publications covering them are also yours for the asking.

Electrolytic Tough Pitch, Fire-Refined, and Other Coppers for Wrought Products, Casting, and Alloying

- **"AMAX COPPER CATALOG"**
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Electrolytic Copper Powders, Copper Alloy Powders, and Pre-Alloyed Filter Powders

- **"AMCO NON-FERROUS METAL POWDERS"**
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OFHC Anodes for Superior Electroplating

- **"THE COPPER IN YOUR PLATING ANODES"**
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REDUCE DOWNTIME

Finkl vacuum degassed steels result in die blocks, hot work die steels, and forgings with greater ductility and toughness. This means that size for size, and/or hardness for hardness, the degassed steel reduces the chances of breakage and excessive wear under severe operating conditions.

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Finkl vacuum degassed steels are cleaner. About 50% of the nonmetallic inclusions have been removed. Machineability is improved, with higher lusters obtainable in die block impressions, if desired. Fewer tool regrinds are required.

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Finkl vacuum degassed steels promote high density centers in large die blocks and forgings therefore reducing the possibility of late shipment because of ultrasonic rejection.

DIE BLOCKS · FORGINGS · HOT WORK STEELS · ELECTRIC FURNACE STEELS

For over 80 years Finkl has been producing top quality products. Now with the introduction of vacuum degassing of our electric furnace steels we have the most complete control of quality which enables us to offer the finest in die blocks, hot work die steels and flat die forgings. Call your Finkl representative.

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Personal Mention

Hal W. Maynor, Jr.

HAL W. MAYNOR, JR., has resigned as associate professor of metallurgical engineering at the University of Kentucky to accept a position with the Alabama Polytechnic Institute in Auburn, Ala. He joined the faculty as professor of mechanical engineering and will be a key member of a research team which will conduct a study of fracture phenomena in certain high-strength metallic materials. The research program is a contractual one, sponsored by the Army Rocket and Guided Missile Agency at Redstone Arsenal, Ala.

It will be his responsibility to develop a metallurgical teaching and research facility designed to supplement and strengthen the program of engineering instruction.

Dr. Maynor received his bachelor's and master's degrees in metallurgical engineering and his doctor's degree in engineering from the University of Kentucky. Before joining the University's faculty, he was a research metallurgist for the General Electric Co., and prior to that was assistant professor in the department of mechanical engineering and associate engineer at the Atomic Research Institute of Iowa State University.

Frank X. McTamney has been promoted to assistant branch manager in the Philadelphia area by the Carpenter Steel Co., Reading, Pa.

Geoffrey Paget has been appointed chief metallurgist for the Shaw Process Development Corp., Fort Washington, N.Y., a subsidiary of British Industries Corp.

Albert H. Fleitman has been appointed to the scientific staff of the Brookhaven National Laboratory. He will participate in physical metallurgy studies on nuclear materials and supervise the new hot metallurgy laboratory of the nuclear engineering division of the laboratory. Before going to Brookhaven, he was assistant supervisor of the physical metallurgy section of the research and development laboratories of the Crane Co. in Chicago.

William B. Stoddard, Jr., has been promoted to manager of electrochemical development for Hanson-Van Winkle-Munning Co., Matawan, N.J. Mr. Stoddard, affiliated with the company since 1957, was formerly assistant manager.

Howard J. Atkinson, formerly sales engineer for Riverside Alloy Metal Div., H. K. Porter Co., is now regional sales manager for Brookfield Wire Co., Inc. (Mass.)

L. F. Yntema is now acting as consultant at Bjorksten Research Laboratories, Madison, Wis., on research and development of foamed metals. Formerly vice-president, director of research, of Fansteel Metallurgical Corp. and senior metallurgist at Stanford Research Institute, Dr. Yntema is well known for his work in inorganic and electrochemistry, rare earths and refractory metals.

Gail B. Hamilton, Jr., has been appointed manager of market development for heaters and devices at the General Electric Co.'s industrial heating department in Shelbyville, Ind. Mr. Hamilton joined the department as a product sales specialist.

Edward Egloff and **Robert E. Graper**, formerly associated with Natural Gas Equipment, Inc., have formed their own corporation, Egloff & Graper, Inc., in Los Angeles to represent two Ohio producers, the Lanly Co., Cleveland, and the Electro-Alloys Div., American Brake Shoe Co., Elyria.

Vernon Griffiths has joined the faculty of the Montana School of Mines as associate professor and head of the department of metallurgy. Dr. Griffiths, a native of the United Kingdom, was formerly a research associate in the department of metallurgy at the University of British Columbia in Vancouver.

John R. Gorey has been named administrative assistant to the general manager of the Western division, Los Angeles plant, of Lindberg Engineering Co., Chicago. Mr. Gorey, affiliated with Lindberg for 17 years, was formerly sales promotion and public relations director.

Robert Fulton, Jr., has been appointed manager of sales for NTH Products Co., Inc., El Cajon, Calif. Prior to joining the company, he was manager of pricing and procurement for Tubesales, Inc., Los Angeles, where he helped establish the firm's eastern division.

A. Daniel Fentzke, a research chemist, has joined the technology department of the Union Carbide Metals Co., a division of Union Carbide Corp., Niagara Falls, N.Y. Mr. Fentzke will be responsible for research leading to the development of new high-temperature materials for use in rockets and guided missiles. His previous affiliations include the refractories division of Babcock and Wilcox Co., the Hydro-Electric Power Commission of Ontario, Canada, and the Niles (Ohio) Firebrick Co.

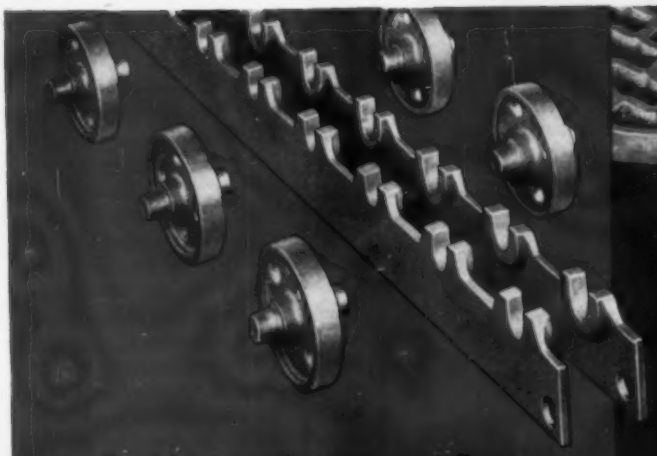
Philip C. Barr, Jr., has been appointed manager of processing of the Toronto, Ohio, plant of Titanium Metals Corp. of America. Mr. Barr, plant metallurgist for TMCA for two years, was assistant department metallurgist specializing in titanium for Allegheny Ludlum Steel Corp. prior to his transfer to TMCA.

A. Richard Boyd has been promoted to district manager of Carpenter Steel Co.'s Atlanta, Ga. territory. Mr. Boyd formerly managed the Atlanta warehouse and was responsible for sales of specialty steels in six southern states.

CASTINGS FOR HIGH TEMPERATURE SERVICE

FAHRITE

HEAT AND CORROSION *Alloys*



Good heat treating parts must first be good castings—with high strength and resistance to thermal shock. At Ohio Steel, careful planning and foundry control assure casting solidity; latest technical advances and non-destructive testing assure consistent high quality in all Fahrite castings.

Among the many types of Fahrite castings made by Ohio Steel are:

Trays	Rotors
Rolls	Radiant Tube Assemblies
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THE OHIO STEEL FOUNDRY CO.

Plants at Springfield and Lima, Ohio SPRINGFIELD, OHIO

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For carbons and sulfurs at high temperatures

Newest, most advanced design for fast determination of carbon and sulfur by combustion in all ferrous metals.

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Drawer-Type Panels for Ease of Access

Instrument panels pull out for ease of inspection, parts replacement and servicing when necessary. All electric components are mounted on the easy-access panel.

Cat. No.	FURNACE	Price
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24-944	Two-Tube Furnace, Model H-2-9	700.00
24-954	Four-Tube Furnace, Model H-4-9	1000.00

For use with 115 or 230 volts, 60 cycle, as specified.
Prices listed are F.O.B. Pittsburgh, Pa.

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Personals . . .

John G. McMullin has resigned as supervisor, metallurgy applied research, for the large steam turbine-generator department of the General Electric Co., Schenectady, N. Y., to accept a position as supervisor, structural alloy research, in the central research laboratory of Crucible Steel Co. of America, Pittsburgh.

LaMar J. Vieau, Jr., has established the Vieau Engineering Co. to represent several manufacturers in the Houston, Tex., area. Mr. Vieau, who was formerly president of Houston Heat Treating Co., is active in the Texas Chapter and is currently secretary-treasurer.

John M. Zabkar has been appointed head of manufacturing operations in the commercial production unit of Sylvania-Corning Nuclear Corp., Hicksville, L. I., N. Y. Mr. Zabkar's background includes 18 years with Westinghouse Electric Corp.'s Sharon Works, Pennsylvania Transformer Co. and Steel-Bilt Construction Co. At the same time, **John Dickson** has been named head of the commercial planning and control department. For 24 years, he was affiliated with the General Electric Co. and had been in the atomic power department in San Jose, Calif., since its inception.

William J. Grierson, formerly associated with Aero-Jet General Corp., has joined the Garrett Corp.'s AiResearch Industrial Div., Los Angeles, as manager of quality control.

Fred E. Storm, chairman of the New Haven Chapter, has joined the Bridgeport Works of the Singer Mfg. Co., Bridgeport, Conn., as consulting plant metallurgist.

Jack E. Morris has been appointed general manager of the container division of Jones & Laughlin Steel Corp., Pittsburgh. He was formerly director of product development in J&L's general office.

Thomas M. Broughton was appointed a sales engineer for Arcweld Mfg. Co., Grove City, Pa. Mr. Broughton, who comes to Arcweld from Riehle Testing Machines Div. of American Machine & Metals, Inc., will serve Western district customers from new offices in Van Nuys, Calif.

SURFACE

COMBUSTION

CORPORATION

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...the most significant breakthrough in heat treating technology in twenty years.

If you could step from a gentle summer breeze into an airstream of gale velocity, you'd get some idea of the vast difference between the convection often used in industrial heat treating and the new Surface Power Convection.

With Surface Power Convection, air velocities of 150 miles per hour or more are not uncommon. The work is heated under precise control in a fraction of the time usually required. Unprecedented product uniformity is achieved. Production per unit of floor space and per dollar of invested capital is raised to levels that were impossible only a few years ago.

Surface Power Convection will be demonstrated at the Metal Show in Booth 648. Be sure to see it.

Surface®

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wherever heat is used in industry

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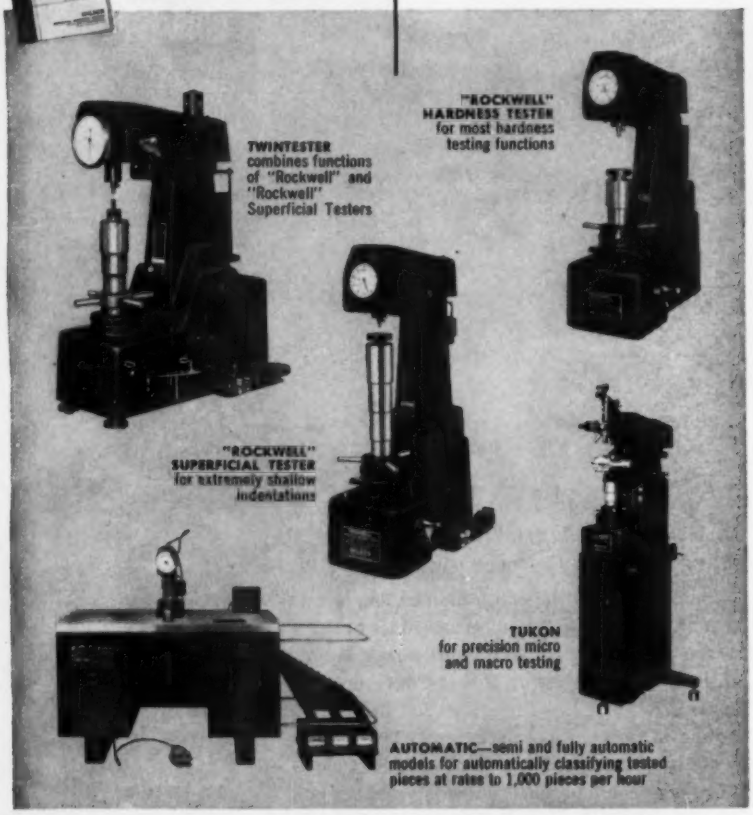
Wilson "Brale" Diamond Penetrators give Perfect Readings

A perfect diamond penetrator is essential to accurate testing. Only flawless diamonds are used with Wilson "Brale" penetrators. Each diamond is cut to an exact shape. Microscopic inspection and a comparator check of each diamond—one by one—assure you of accurate hardness testing every time.

Write for Catalog RT-58. It gives complete details on the full line of Wilson hardness testing equipment.


TWINTESTER
combines functions of "Rockwell" and "Rockwell" Superficial Testers
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for most hardness testing functions
"ROCKWELL" SUPERFICIAL TESTER
for extremely shallow indentations
TUKON
for precision micro and macro testing
AUTOMATIC—semi and fully automatic models for automatically classifying tested pieces at rates to 1,000 pieces per hour

WILSON "ROCKWELL" HARDNESS TESTERS

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Wilson Mechanical Instrument Division
American Chain & Cable Company, Inc.
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Personals . . .

Robert F. Mehl, cited as one whose "name is virtually synonymous with modern metallurgy", was awarded one of the highest honors in engineering education at the American Society for Engineering Education annual meeting in Pittsburgh last summer. Dr. Mehl, dean of graduate studies at Carnegie Institute of Technology and head of the metallurgical engineering department and the Metals Research Laboratory, received the Vincent Bendix Gold Medal for "his pioneering study of the fundamental concepts of the nature and behavior of metals, for the vigorous research program which he directed and in which he has personally participated, and for his impact upon the careers of his many students and associates". Dr. Mehl was also honored by two universities – he received honorary degrees from Case Institute of Technology and the University of Pennsylvania.

F. C. Langenberg has been appointed manager of process research for the Crucible Steel Co. of America, Pittsburgh. Formerly chief development metallurgist at the company's Midland, Pa., works, he will now be responsible for developing technical specifications for all process research facilities at the Crucible Technology Center.

Edward L. Badwick, formerly production engineer with Bendix Aviation Corp., at the semiconductor division in Long Branch, N.J., has been appointed plant manager of Accurate Specialties Co., Inc., Woodside, N. Y.

H. B. Hebble, who has been working on the development of vacuum induction melting of uranium for the past two and one half years at the National Lead Co. of Ohio in Cincinnati, has joined the vacuum metallurgical department of F. J. Stokes Corp., Philadelphia, as product specialist on vacuum melting equipment.

Charles W. Ashcom has been appointed chief metallurgical engineer, engineering and planning division, at Kaiser Steel Corp.'s Fontana, Calif., plant. In his new capacity, Mr. Ashcom will head the newly created department of metallurgical engineering.

fundamentals of SURFACE POWER CONVECTION

So great is the difference between ordinary convection and Surface Power Convection that it will be well to discuss this development in the light of a few fundamentals.

A heat treating furnace is essentially a device in which heat transfer by radiation, convection, and conduction takes place under control, to put parts through a time-temperature cycle.

Heat transfer by conduction serves primarily to distribute heat within the work-piece. Transfer of heat to or from the parts is by radiation and convection.

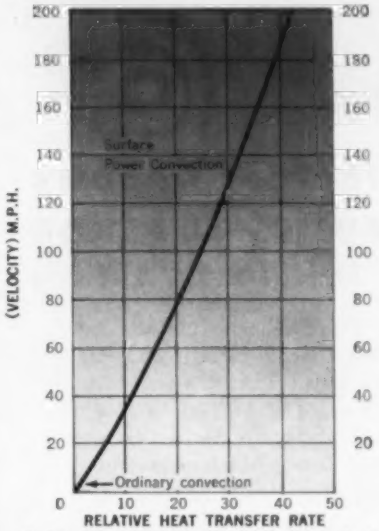
To speed production, we can increase the rate of radiant heat transfer with very high "thermal heads," in other words, with very hot "radiators."

We soon encounter many limitations, however. The geometry of the work-pieces or the load of parts in the furnace may cause parts of the work to overheat long before the main mass of the part or load is up to temperature. Differences in surface quality or color will change the heat absorbing ability of the metal and result in uneven heating and non-uniform results. Furthermore, when "radiator" temperature is substantially above desired maximum work-piece temperature, control of heat transfer rate is critical and difficult.

Finally, thermal heads are limited by the very practical problem of the maximum operating temperatures of the materials feasible for radiators and other structural material in the furnaces—usually about 2000° F.

On the other hand, with *convection*, we can increase the rate of heat transfer without such critical control problems or dangers of overheating, by raising the velocity of air movement and maintaining only a relatively small thermal head.

The amount of heat transferred to the work is now determined mainly by the velocity of air movement, and hence we can raise the upper limits of heating rates very significantly. The desirability of convection heat transfer at extreme velocity has long been known; its advantages in terms of improved uniformity, increased speed, and reduced floor space are clear.



Surface Power Convection utilizes the highest air velocity to achieve a maximum heat transfer coefficient consistent with application requirements.

Why, then was Power Convection not developed long ago? Chiefly because the engineering design problems—involving mechanics, aerodynamics, thermodynamics, metallurgy, to name only a few—were so formidable. For instance, fan blades had to be designed for maximum aerodynamic performance, to operate continuously under high dynamic stress at elevated temperatures. This brought a host of problems unheard of in conventional furnace design and manufacture. Soon it became apparent that air movement patterns were determined not just by fan design but by the geometry of the parts, density of loading, configuration of the furnace interior, baffles and work handling devices.

It was not enough just to build fans that would function in extreme environments: it was a matter of accumulating a wealth of new data on high temperature convection in a range of velocities never before explored, then solving a large array of interrelated problems so that reliable predictions of furnace performance could be made.

In effect, the furnaces would behave like wind tunnels, handling air at temperatures close to the physical limits of our materials. This is what Surface has developed over a period of years.

We can now present and define a new measure of furnace performance: *convection power*—a rating of the capability of a furnace to transfer heat to its work load primarily by convection, with great speed, uniformity, and efficiency. And convection power can now be evaluated in economic terms.

While some problems remain to be fully worked out, we have charted such a large area of this new technology that we can say with confidence:

Surface Power Convection raises the capabilities of heat treat production significantly above previously accepted limits of performance. Cooling as well as heating is remarkably speeded up, and the uniformity of heat treatment in controlled atmospheres is improved.

Surface Power Convection now permits designing furnaces with heat transfer rates limited not by our abilities to produce and distribute heat, but by the physical abilities of work-pieces to absorb it.

Write for Bulletin SC-182 for further data on this new development.

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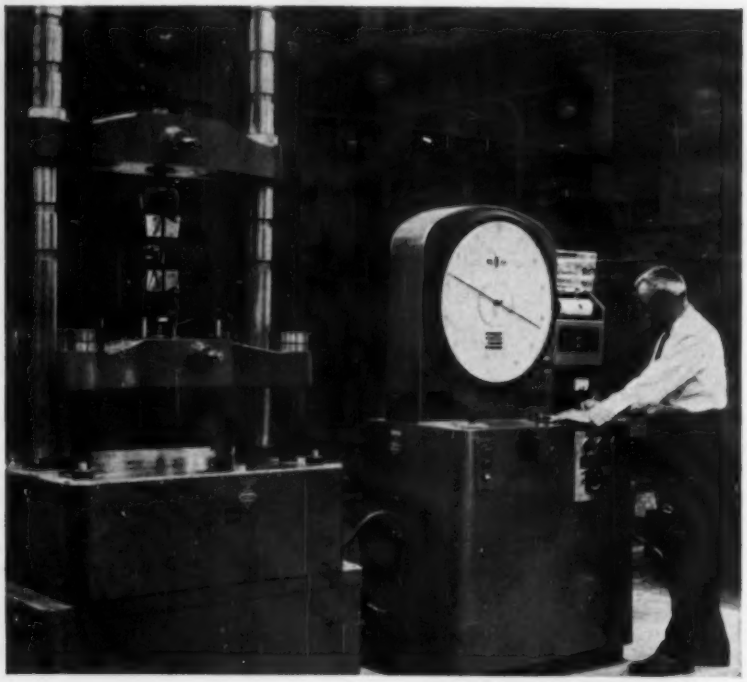

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Materials used in the Atlas intercontinental ballistic missile must meet exacting specifications to withstand the tremendous stresses and strains of outer space flight. Time is at a premium. Testing accuracy and reliability are assured by a Tinius Olsen Elec-matic Universal Testing Machine used in the San Diego plant of Convair (Astronautics) Division of General Dynamics Corp.

Uniform testing speeds are maintained throughout the test by the variable speed motor drive. Any of four ranges, of as little as 1/100 capacity, can be selected during test. In addition, materials under test can be subjected to varying conditions of stress and strain with a built-in automatic cycling program controller.

Evaluate your testing program in terms of the unmatched flexibility and accuracy of a Tinius Olsen Elec-matic—available in capacities from 500 to 1,000,000 lbs. Write for Bulletin 54 today.

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Personals . . .

James McSharry has joined the research and development group of Mallory-Sharon Metals Corp., Niles, Ohio, as staff assistant for work in extractive metallurgy. While Mr. McSharry will be stationed at the Niles laboratory, he will work closely with the company's titanium and zirconium reduction plants.

Kenneth P. Seeger has joined the staff of Precision Extrusions, Inc., Bensenville, Ill., as chief metallurgist. His past experience includes 18 years in the aluminum extrusion field, most recently as plant metallurgist for the Aluminum Co. of America at Lafayette, Ind.

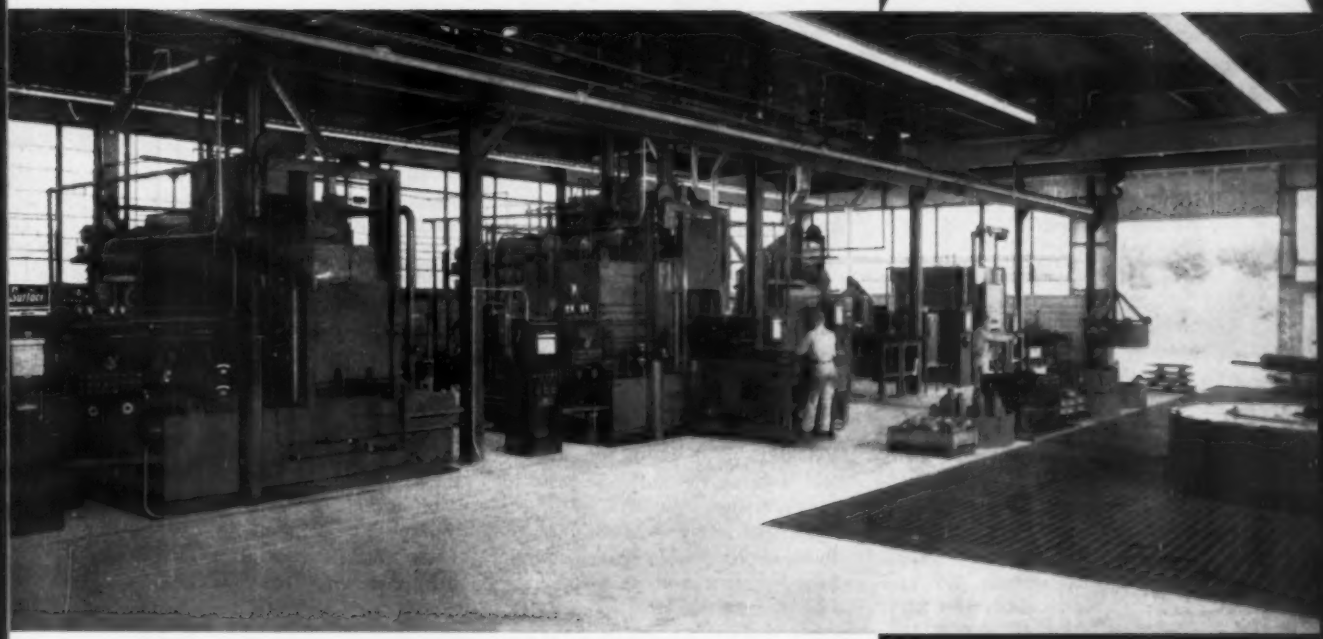
Arnold L. Boyce was recently appointed superintendent of Indox at the Indiana Steel Products Co.'s new plant in Valparaiso, Ind. Prior to his association with Indiana Steel, Mr. Boyce was with the Ford Motor Co. as a metal powder engineer and served as assistant superintendent in the powder metal department at the Morine Products Div. of General Motors Corp.

Charles S. Fee has been appointed project manager in charge of ceramic fuels contracts for the commercial production unit of Sylvania-Corning Nuclear Corp., Hicksville, L. I., N. Y. Other appointments in the company include **B. H. Francis**, named project manager for PRDC reactor fuel production, generally known as the Enrico Fermi fast breeder reactor at Detroit, and **William G. Lidman**, formerly with Sylvania Electric Products in the nuclear energy field and associated with Sylcor since its inception, now project manager in charge of coordinating all activities bearing on the Army Package Power Reactor, for which Sylcor is fabricating the second complete loading.

R. Thornton Beeghly has been elected president of Metal Carbides Corp., Youngstown, Ohio. He joined the company in 1934 and has been vice-president and general manager since 1936.

Marvin B. Happ, former chief metallurgist with the Walworth Co., has joined Tang Industries, Waltham, Mass., as assistant general manager.

stop temperature variations in high density loads with SURFACE POWER CONVECTION



Exceptional uniformity and speed of heat treating, regardless of load density, help make a consistent profit-maker of this mechanized line of Surface batch-type furnaces at The Milwaukee Gear Company.

Because of Surface Power Convection, Milwaukee Gear has much greater metallurgical control and uniformity of product than ever before. High-velocity wind penetrates the tightest loads; assures uniform heat transfer whatever the size, shape, or alloy of the work.

Carburizing case depths are hit right on the button which vary from a few thousandths to 3/16 of an inch. This unusually flexible standard rated furnace line consists of two Super Allcase® furnaces, a horizontal draw furnace, spray washer, DX® and RX® gas generators, and Autocarb® signalling dewpoint controller.

Surface Power Convection cuts cycle times to a fraction.

These advantages only suggest the profitability of Surface Power Convection. Ask your Surface representative to describe the most important development in convection heat transfer in 20 years.

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Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Strength of Martensite

Digest of "The Strength of Martensite Formed From Cold Worked Austenite", by J. C. Shyne, V. F. Zackay and D. J. Schmatz, Preprint No. 163, 1959.

THE AUTHORS discuss some results of their very interesting research on the effects of hot-cold working metastable austenite on the strength of martensite formed on subsequent cooling. Five steels (three air melts and two vacuum melts) were studied. The air melts were essentially a 2.0% Cr, 1.5% Si, 1.0% Mn, 1.0% Ni, 0.4% Mo and 0.3% V steel with carbon content between 0.3 and 0.5%. The vacuum melts were 3.0% Cr, 1.5% Si, 1.5% Ni, 0.75% Mn, 0.4% Mo with 0.5 to 0.6% C. Both steels have a wide bay (in the TTT diagram) between the pearlite and bainite transformation ranges; in these, metastable austenite can be severely hot-cold worked. Austenite deformations up to 93% reduction in area were studied.

The yield strengths of martensites formed from hot-cold worked austenites are summarized in Table I. Data were estimated from the curves in the paper. The yield strength of the as-formed martensite (212° F. temper) was increased as much as 50,000 to 70,000 psi. by severely cold working the austenite prior to transformation.

The tempering behavior of martensite from deformed austenite is quite different from that from undeformed austenite. The yield strength of the martensite of the undeformed air-melted steels decreases or remains essentially independent of tempering temperature up to 600 to 700° F. However, the yield strength of all of the severely cold worked steels increases as much as 60,000 to 90,000 psi. on tempering at 600 to 700° F. Thus, adding the increased yield strength due to austenite deformation in the untempered condition to the additional increase resulting from tempering gives a total higher yield strength by austenite deformation of as much as 145,000 psi. This means yield strengths in the 350,000 to 400,000 psi. range. It should be pointed out that the data are for tests in the direction of working.

The ductility of these very high strength steels is not bad (4 to 9% elongation) at least for the vacuum-melted heats. No ductility data are reported for air melt compositions.

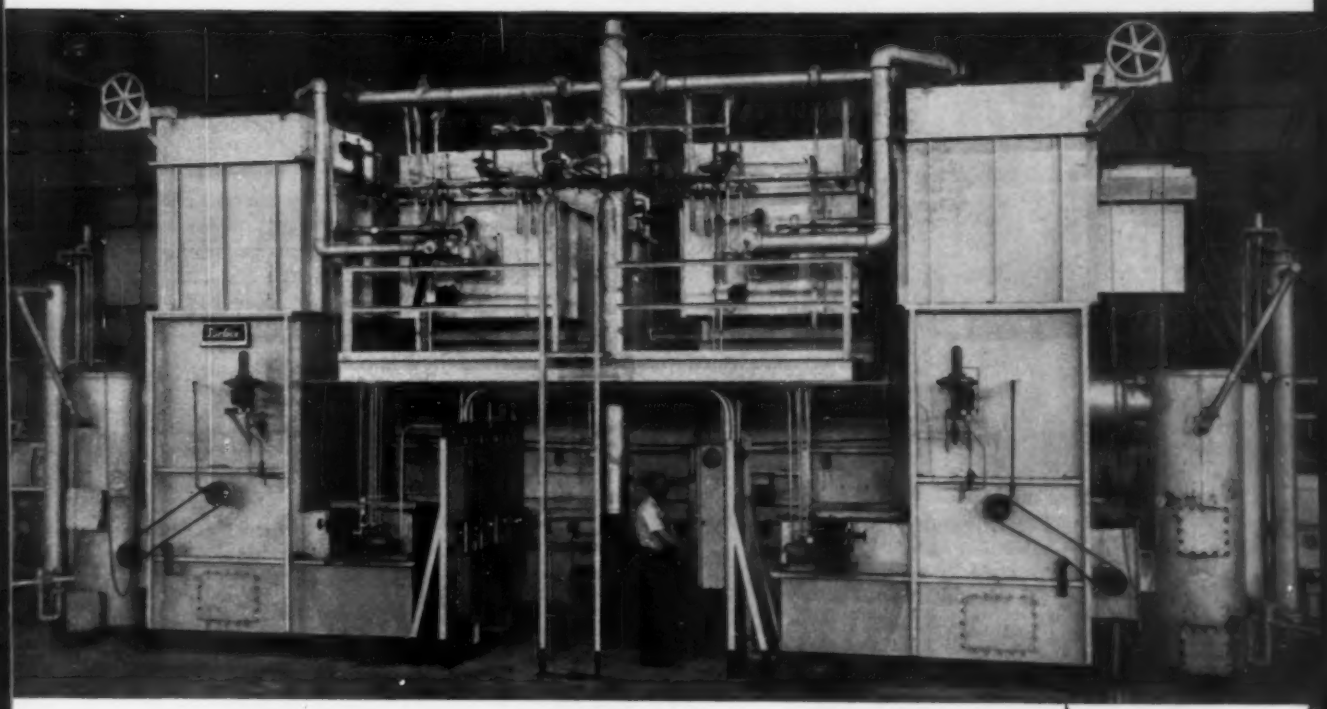
Plastic deformation of the austenite resulted in a finer martensite, and the martensite plate length was roughly proportional to the degree of austenite deformation. Yield strength was found to be a linear function of the reciprocal of the square root of the martensite plate length. Consequently, the authors appear to believe that the main effect of deforming the austenite is to decrease the martensite plate size.

This paper should be on the "must read list" of all metallurgists. Undoubtedly the technique of hot-cold working austenite prior to transformation to martensite is a powerful new tool for changing the properties

Table I — Yield Strength of Martensite Formed from Hot-Cold Deformed Austenite*

Carbon	212° F. Temper		700° F. Temper	
	Unworked Austenite	Austenite, Worked 90%	Unworked Austenite	Austenite, Worked 90%
	Air-Melted Alloys			
0.31%	230,000 psi.	300,000 psi.	230,000 psi.	360,000 psi.
0.41	255,000	325,000	260,000	395,000
0.47	265,000	325,000	265,000	395,000
	Vacuum-Melted Alloys			
0.48	230,000	290,000	250,000	365,000
0.63	250,000	320,000	290,000	395,000

*Data estimated from curves in paper.



SURFACE POWER CONVECTION

speeds annealing rate to 8,000 lbs/hr of brass tubing

This furnace is one of Scovill Manufacturing Company's (Waterbury, Connecticut) answers to the threat of imported brass and copper mill products.

Scovill is after new highs in production and quality in its new streamlined tube mill at New Milford, Conn. This continuous roller hearth furnace, equipped with Surface Power Convection, helps achieve both goals. It anneals and cools 8,000 lbs. of brass and cupro-nickel tubing an hour. At the same time, it produces tubing of superior physical properties because it maintains temperature uniformity at plus-minus 8° F.

Such process speeds and temperature uniformity are possible only with Surface Power Convection, the most important advance in convection heat transfer in 20 years. Ask your Surface representative how you can apply this profitable new technology to your products. Write for Bulletin SC-182.

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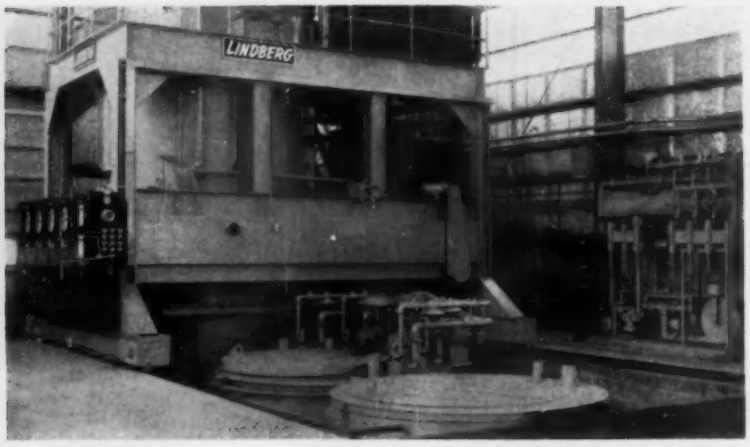
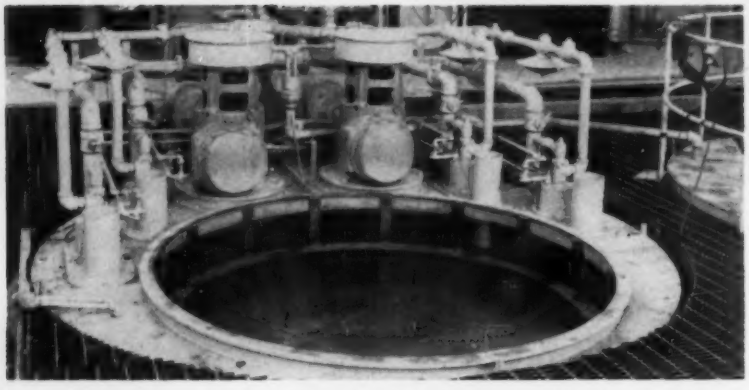


Motor cases for a 24-foot missile go into this gantry-type furnace at Lindberg Steel Treating Company . . .



. . . and come out of these quench tanks at uniform hardness.

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The two turbine-type mixers circulate 240,000 pounds of molten salt at 400 to 1000° F over four radiant heating and cooling tubes and through the work load in the 25-foot-deep bath.

Controlled circulation insures complete transformation and promotes uniform hardness depth when quenching a work load as large as 80″ in diameter by 288″ long, weighing as much as 6000 pounds.

Installed close to the batch surface and exposed to high temperatures, each 15-hp mixer has built-in provision for water-cooling the hollow upper shaft, thus minimizing the temperature of the reducer and shaft bearing areas.

LIGHTNIN Mixers are made in sizes from 1 to 500 hp for new or existing quench tanks—for use with any quenchant, any type of immersion quenching, pieces of any size, shape, quantity. They are recommended by leading steel producers, used as standard equipment by leading furnace manufacturers. For complete information, call your nearest LIGHTNIN Mixer representative (listed in Thomas' Register) or write us.

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Martensite . . .

of steel. Much additional information is needed. Particularly interesting would be data on the impact transition temperature and the tensile and impact properties of specimens taken normal to the direction of deformation.

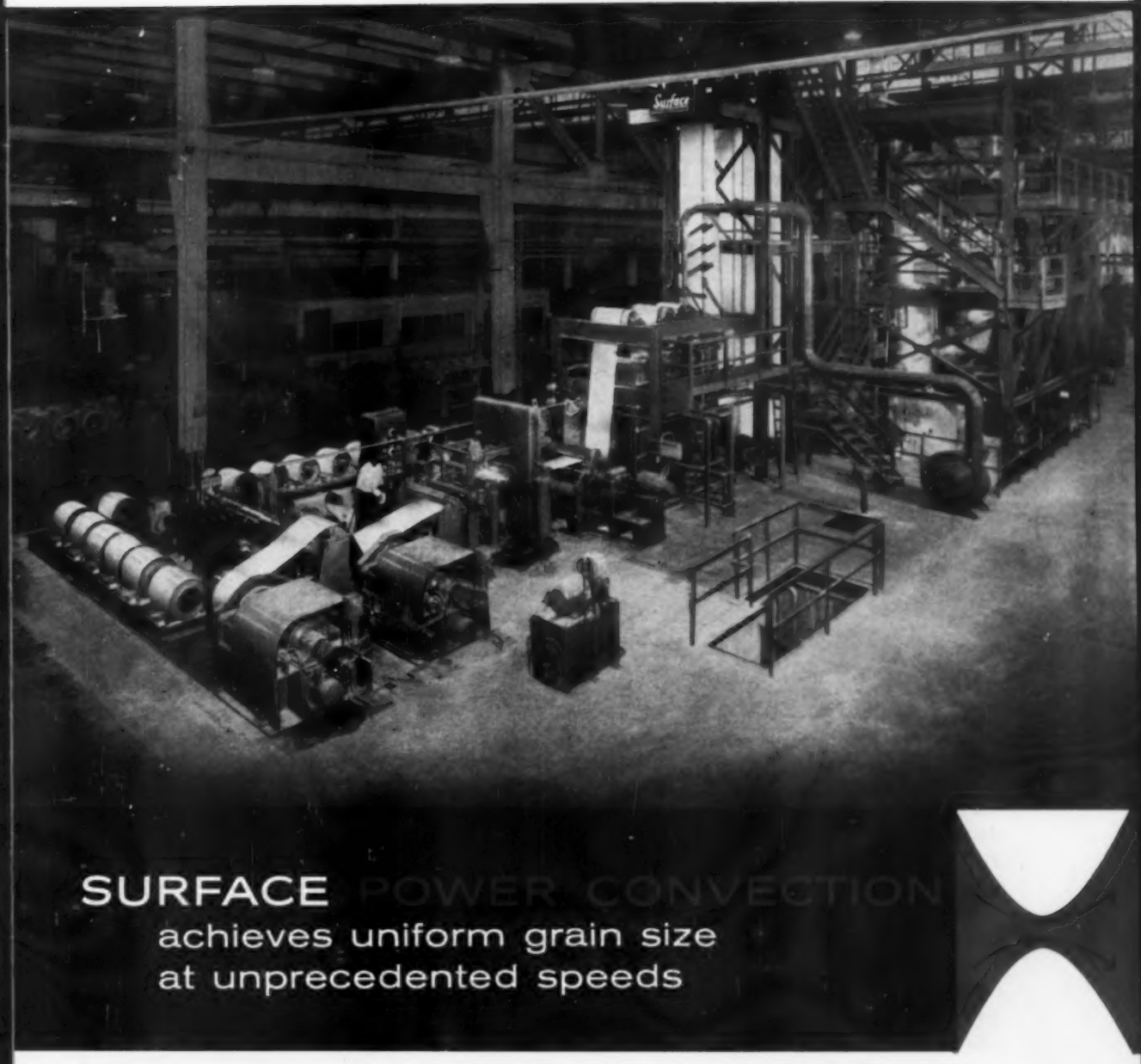
J. H. BECHTOLD

Hot Working Ferrous Materials

Digest of "The Effect of Initial Increments of Hot Working on the Mechanical Properties of Certain Ferrous Materials", by H. J. Wagner and J. W. Spretnak, AIME Preprint No. 170, 1959.

FREQUENTLY many intermediate operations are required to hot forge a square or round ingot to a complex shape. Consequently, the use of precast blanks, approximating the final shape, has been suggested for minimizing these steps, thereby cutting costs and increasing production. The success of forging precast blanks hinges on obtaining the desired mechanical properties by relatively small hot reductions. This work was initiated to learn the relationship between such small forging reductions and mechanical properties. It was planned to learn also how this relationship is affected by chemical heterogeneity, inclusion content, and direction of testing.

In this investigation all hot working was done by slow upset forging in a hydraulic press. Preliminary tests showed that the amount of deformation varies substantially from point to point in the upset forging. Consequently, for getting mechanical-test specimens with a specific amount of hot work, it was necessary to first develop a method for determining relatively accurately the amount of deformation at specific locations in an upset forging. This was done by studying the flow pattern in two pieces of hot rolled A.I.S.I. 1010 steel machined to the same size (3.5 in. diameter by 4 in. high) as the experimental cast billets in the main study. Along a median longitudinal plane of each billet, vertical ⅛-in. holes were drilled ½ in. apart. High-carbon steel rods were inserted in the holes. These



SURFACE POWER CONVECTION achieves uniform grain size at unprecedented speeds

This Surface line is designed to continuously heat brass strip at speeds up to 200 feet per minute.

But unprecedented process speed is not the only profit which can be credited to Surface Power Convection, which heats the strip. Equally important are uniform control of grain size from edge to edge, and improved surface quality.

The key to such high-speed high-quality production is the tremendous wind velocity achieved by Surface Power Convection. In this furnace, wind speeds reach 136 miles per hour—a velocity unheard-of in convection furnaces up to now.

And the best news about Surface Power Convection is that it can be applied to virtually any type of heat treating equipment you can think of—batch or continuous, direct or indirect fired, straight air or atmosphere.

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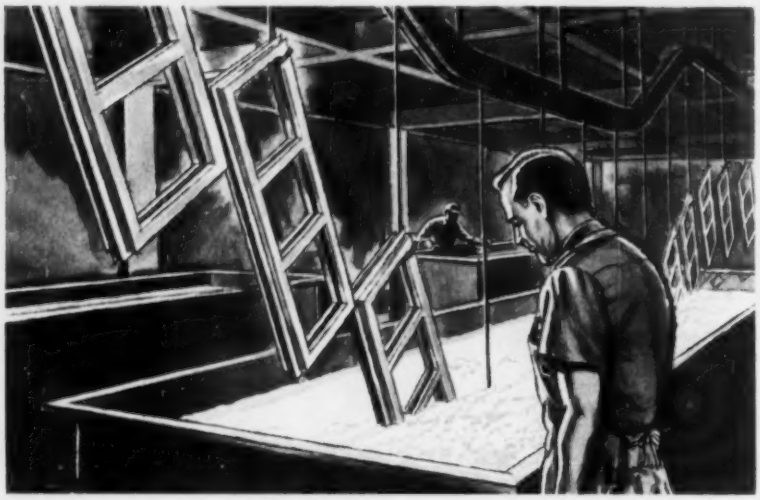

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Hot Working . . .

billets were then upset forged (along with those in the main study) to 1.4 and 2.1 initial-to-final height ratios, and sectioned through the rods to illustrate the metal flow pattern produced by forging. The photomacrographs included in the appendix of this paper indicate the flow pattern.

Now to return to the main problem. To separate the effects of inclusions and chemical heterogeneity, the study used electrolytic iron and A.I.S.I. 4340 steel, each with low sulphur (0.002%) and high (0.15%). These materials were melted in air in a 200-lb. induction furnace, deoxidized with aluminum (2 lb. per ton) and cast as 4 × 4 × 16-in. ingots. Cylinders, 3.5 in. in diameter by 4 in. high, were machined for forging as described in the preceding paragraph. The cylinders were

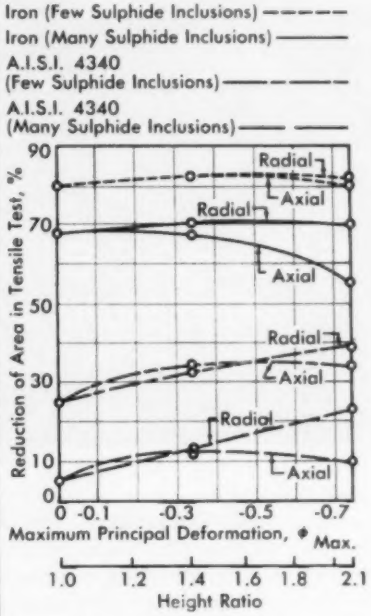

Fig. 1 – Effect of Degree of Deformation on Average Reduction of Area

heated to 2200° F., held for 1 hr., upset forged and cooled in air. To simulate this condition, the unforged control cylinders also were austenitized for 1 hr. at 2200° F. and air cooled. To increase the validity of the results, 7 to 13 replicate specimens were used in this investigation

(*Continued on p.* 176)

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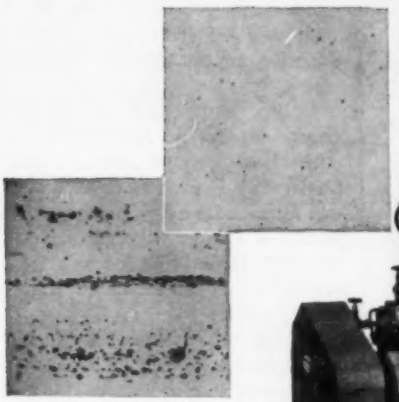

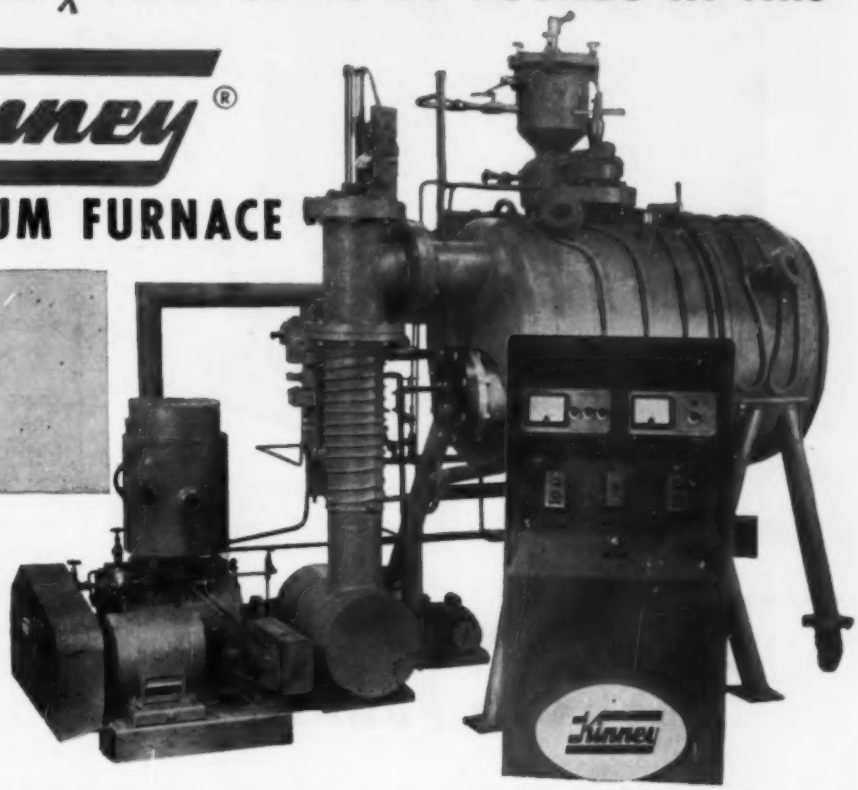

Above—Cross section of vacuum molded billet. *Below*—The same metal but cast in atmosphere.

When you can't afford to let gases reduce the quality of your castings and run reject rates out of sight, the practical money-making aspects of KINNEY High Vacuum Furnaces assert themselves. The 50 pound model shown has found excellent application with high nickel steel, carbide tool steel, uranium and other metals. But, the value of this KINNEY Furnace is not confined to the more exotic metals . . . low alloy steels are dramatically improved by vacuum processing.

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STOKES

Hot Working . . .

for each condition of forging reduction, inclusion content and chemical composition.

The experimental results comprise room-temperature tensile data in the axial (transverse) and radial (longitudinal) directions. The results are limited to initial-to-final height ratios of zero, 1.4 and 2.1. Forging of iron and 4340 steel to a height ratio as great as 2.1 has no significant effect on the tensile strength, either with high or low sulphur. This observation implies that chemical heterogeneity does not influence the independence of tensile strength and degree of forging, because the independence is found both in a fairly homogeneous material, iron, and in one much more heterogeneous, 4340 steel. A number of earlier investigators also found that degree of forging has no significant effect on tensile strength.

On the other hand, ductility, as measured by reduction of area in the tensile test, is affected significantly by the degree of forging, as shown by the average values in Fig. 1. This also has been observed by earlier workers. The maximum ductility in the axial (transverse) direction is reached at the height ratio of 1.4 for all four materials under study. Further forging lowered or had little effect on the axial ductility. Forging reductions ranging up to the 2.1 maximum height ratio improved the radial (longitudinal) ductility of the 4340 steel, but not of iron probably because of its homogeneous nature. The presence of sulphide inclusions increased the difference between the axial and radial ductilities in both iron and 4340 steel. Increasing the forging, by increasing the height ratio from 1.4 to 2.1, was found to result in greater directionality of the ductility and in a wider spread of the ductility values in both directions.

In summary, the results of this work suggest, but do not prove, that it may be feasible to increase the productivity of the forging industry by rough casting blanks of normal, or better, soundness to the approximate shape of the final product, thus minimizing the number of forging-press operations.

O. O. MILLER

(*More digests on p.* 194)

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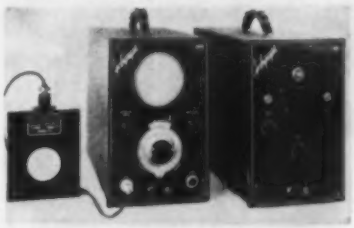

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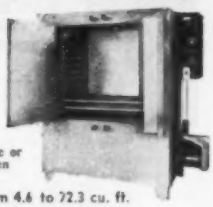

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Get full information on the spectacular economy and precision of the Cavitron—Write to The Sheffield Corporation, Dayton 1, Ohio, U.S.A., Dept. JP.

LIST NO. 235 ON INFO-COUPON PAGE 186

LA-CO
Aluminum Soldering Flux
Now . . . Solder Aluminum with ordinary soft solders

- Use 60-40, 50-50, 40-60, 95-5 solders
- No new soldering techniques
- Non-acid . . . Self-cleaning

A major breakthrough in aluminum fabrication. Use ordinary soft solders . . . ordinary irons or torches. Remarkable fluxing action achieves perfect bond of aluminum and solder making possible the fabrication of aluminum to aluminum, copper, steel, stainless steel, galvanized iron, brass, etc.

Write for sample, or engineering help on any fluxing problem.

LA-CO BRAND
LAKE Chemical Co.
3079 W. Carroll Ave., Chicago 12, Ill.

LA-CO
Silver Solder Flux
Greater speed and economy for all silver soldering!

- Packed in tins
- Will not harden
- Non-acid . . . Self-cleaning

For all silver soldering in 1125° to 1700° F. heat range. Dissolves all refractory and non-refractory oxides . . . solder penetrates completely into all areas, for maximum strength without solder waste. Completely acid-free—will not pit or stain metals. Always-ready paste form . . . will not harden or crystallize.

Write for sample, or engineering help on any fluxing problem.

LA-CO BRAND
LAKE Chemical Co.
3079 W. Carroll Ave., Chicago 12, Ill.

LA-CO
Stainless Steel & Chrome Soldering Flux
Safer . . . Surer . . . Cleaner

- Doesn't stain
- Non-acid
- Self-cleaning

For soldering all stainless steel and chrome, including 300-400 Series, with ordinary soft solders. Requires no pre-cleaning. Acid-free formulation will not pit metals, leaves no stains. No buckling on even light gauge work. In liquid or paste form.

Write for sample, or engineering help on any fluxing problem.

LA-CO BRAND
LAKE Chemical Co.
3079 W. Carroll Ave., Chicago 12, Ill.

LIST NO. 202 ON INFO-COUPON PAGE 186

make hardness tests ANYWHERE WITH THE

NEWAGE TESTER

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
- NO CONVERSIONS OR CALCULATIONS
- TEST ANY SIZE, SHAPE OR TYPE METAL
- NO SKILL REQUIRED
- SCALE READINGS IN ROCKWELL & BRINELL
- ACCURACY GUARANTEED

Many thousands used by industry and government. Write, wire or call for additional details and prices.

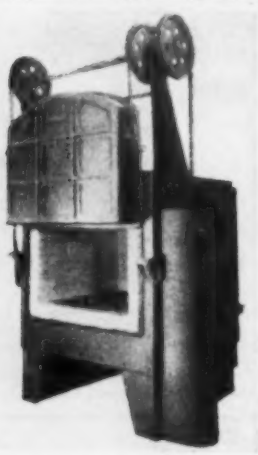
NEWAGE INDUSTRIES, INC.
222 York Road, Jenkintown 0, Pennsylvania
TUrner 4-6496 — Dept. MP

LIST NO 163 ON INFO-COUPON PAGE 186

GOOD USED EQUIPMENT AT REAL SAVINGS TO YOU!

SACRIFICE BEFORE MOVING!

Lindberg Cyclone Box-Type Tempering Furnace



Model 243618 EH, electric heated for 1250° F. Recirculating type, with inside working dimensions 24 in. wide by 36 in. deep by 18 in. high. Electrical characteristics, 220/440/60/3/27 kw, or convertible to gas. Complete with control panel, strip chart recording and controlling instrument, magnetic contactors, disconnect switch, thermocouple, etc.

Also in stock for immediate delivery. New blowers, alloy trays and baskets, burners, solenoid valves, thermocouples, etc.

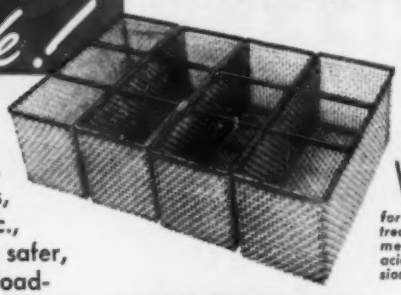
Our stock is constantly changing! Before you buy any furnace or accessory, call us collect and let us show you how to save money! (Money-Back Guarantee.) We pledge that any unit we advertise is in stock at one of our warehouses at the original time of publication. However, they are subject to prior sale, so act now!

METAL TREATING EQUIPMENT EXCHANGE, INC.
9825 GREELEY ROAD
DETROIT 11, MICHIGAN

LIST NO. 142 ON INFO-COUPON PAGE 186

Custom Made!

all styles, metals, weaves ...any size, quantity!



Wiretex engineers Baskets, Muffles, Screens, Fixtures, Grids, Racks, etc., to insure easier, safer, loading and unloading; greater space saving, better draining and cleaning.

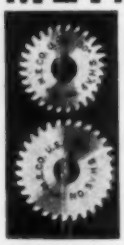
Call Wiretex

for all your heat treating requirements to resist acid, heat, abrasion or exposure.

Wiretex mfg. co.
5 Mason St., Bridgeport 5, Conn.
Specialists in Processing Carriers Since 1932.

LIST NO. 114 ON INFO-COUPON PAGE 186

MARTINDALE METAL SAWS



for fast, precision sawing, slotting, mica undercutting

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HIGH SPEED STEEL OR TUNGSTEN CARBIDE

Milled, hardened and ground by skilled, experienced craftsmen to exacting specifications. Available in ¼" to 4" O.D., complete range of thicknesses and tooth designs, "U" slot or "V" cutters. Get finest saw blade performance—lowest operating cost.

Send for NEW CATALOG and prices on these and other maintenance, safety and production products.

MARTINDALE ELECTRIC CO.
1372 Hird Avenue — Cleveland 7, Ohio

LIST NO. 216 ON INFO-COUPON PAGE 186

Whitelight MAGNESIUM

your comprehensive independent mill source of magnesium alloy . .

ALLOYS
AZ10
AZ31
AZ51
AZ61
AZ81
ZK60
ZK30
M-1
ZK-20
Anodes

RODS ½" dia. to 6½" dia.
BARS, STRIPS .022" min. to 7½" max
SOLID SHAPES .022" min. to 6½" circle
TUBING ½" O.D. to 6" O.D.
HOLLOW SHAPES ½" to 5½" circle
PLATE & SHEET .092" to 3" thick

WHITELIGHT MAGNESIUM

WHITE METAL ROLLING & STAMPING CORP.
82 Moultrie Street, Brooklyn 22, N.Y.
Factories: Brooklyn, N.Y. • Warsaw, Ind.
Los Angeles Warehouse: 6601 Telegraph Rd.

LIST NO. 238 ON INFO-COUPON PAGE 186

FREE **POWDERED METAL BOOKLET . . .**

Gives cost-cutting hints, including:

- Illustrated description of Remet powdered metal process
- Design DO's and DON'T's for powdered metal parts
- Advantages and limitations of Remet process

For your copy write to . . .

REESE METAL PRODUCTS CORPORATION
537 Howard Ave. • Lancaster 12, Penna.

Gears • Pinions • Cams • Ratchets • "Oilless" Bearings • Bushings • Machine and Structural Parts in COPPER • BRASS • IRON • ALLOY STEEL • NICKEL SILVER • COPPER INFILTRATED IRON

LIST NO. 233 ON INFO-COUPON PAGE 186

DO YOU HAVE AN IDEA...

THAT SOME FUNCTIONAL METAL PART COULD BE MADE BETTER OR CHEAPER BY ALUMINUM EXTRUDING?

Bring your idea to specialists in adapting aluminum extrusions to new functional part: applications. G. E. I.'s engineers are ready to consult with you, without obligation, on one part or a million.

GENERAL EXTRUSIONS, INC.
4040 LAKE PARK RD., YOUNGSTOWN, OHIO

Mill Representatives at St. Louis, Detroit, Pittsburgh, Cincinnati, and Chattanooga. Consult your classified phone book under Aluminum Products

LIST NO. 141 ON INFO-COUPON PAGE 186

How to Cut Pot Costs:

Buy low-cost Eclipse pressed (not welded) steel pots . . . and replace them on a regular schedule.

1 Lower initial cost
2 Elimination of failures
3 Faster, more even heating
4 Quantity discounts earned on your total purchases in any 12 month period.

Guaranteed free from defects. Write:
Eclipse Fuel Engineering Company
Industrial Combustion Division
1127 Buchanan St., Rockford, Ill.

Eclipse PRESSED STEEL POTS

LIST NO. 176 ON INFO-COUPON PAGE 186

SUB-ZERO
low temperature equipment

for

- shrink fits
- seasoning gauges
- precision tools
- laboratory testing

1.5 and 6.5 cu. ft. capacities. Sturdy, all-steel cabinet construction. Sublids for constant inside temperature. Adjustable temperature controls. Special accessories available.

For more information— Write to: **Revco INC.**
Deerfield, Michigan
Specialists in Trend-Setting Refrigeration

LIST NO. 200 ON INFO-COUPON PAGE 186

HIGH VACUUM
for
laboratory or production . . .

THIS HIGH VACUUM PORTABLE PUMPING STATION

. . . is unequalled in quality and performance — and unmatched in price!

HIGH VACUUM EQUIPMENT CORPORATION
HINGHAM, MASSACHUSETTS

LIST NO. 223 ON INFO-COUPON PAGE 186

Regulate and control electric ovens and furnaces better, accurately, and efficiently with

SORGEL
Saturable Reactors

Any amount of A.C. power from 1 Kva to 3000 Kva, single phase or 3-phase, at any voltage, can be controlled, regulated, and varied in stepless increments, with SORGEL Saturable Reactors.
The control can be a small manually operated hand wheel that can be placed in any desired location, or it can be automatically controlled, regulated and varied by a thermostat or any other instrument or device.
SORGEL reactors are designed to meet your exact requirements. Let us know what your problems and requirements are, and we will submit our recommendations with complete information.

Write for Bulletin 658.

Saturable Reactor with tap changing transformer

•

Also a complete line of dry-type transformers.

All standard and intermediate ratings, ¼ Kva to 10,000 Kva, 120 to 15,000 volts.

•

Sales Engineers in principal cities

Consult the classified section of your telephone directory, under the heading "Transformers," or communicate with our factory.

Sorgel Electric Company
834 W. National Ave., Milwaukee 4, Wis.
Over 40 years of electrical manufacturing development

LIST NO. 195 ON INFO-COUPON PAGE 186

DUCTILE IRON PLATE
A MARRIAGE OF THE PHYSICAL AND MECHANICAL PROPERTIES OF STEEL & IRON

EASY TO MACHINE — WILL FLAME CUT
SUPERIOR WEAR CHARACTERISTICS
EXCELLENT HARDENABILITY
DIMENSIONAL STABILITY

YIELD POINT
50,000 PSI TO 90,000 PSI
MODULUS OF ELASTICITY
24,000,000 PSI

DIES — SURFACE PLATES — BOLSTERS
FLOOR PLATES — PLATENS — WORK TABLES
FRAMES — BASES, ETC.
1000 LBS. TO 20 TONS

LINDGREN FOUNDRY CO.
BATAVIA, ILLINOIS
PHONE 1800

LIST NO. 231 ON INFO-COUPON PAGE 186

DOW
BATCH FURNACES
CONTROLLED ATMOSPHERE EQUIPMENT FOR EVERY APPLICATION

STANDARD HEARTH SIZES
20" Wide—30" Long
24" Wide—36" Long
30" Wide—48" Long

LIST NO. 230 ON INFO-COUPON PAGE 186

HEVI-DUTY Tube Furnaces for Tensile and Creep Testing Machines

Split tube furnace features three zones of temperature control to 2200° F.

- Assure stable, uniform heat in multiple zones.
- Temperature ranges to 1850, 2200 or 2600° F.

Hevi-Duty Vertical tube furnaces feature multiple zone heating. Precise temperature control is assured by use of stepless variable transformer that regulates each heating zone. Units are available in split tube and solid tube designs, complete with all instrumentation.

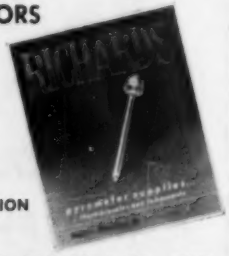
HEVI-DUTY — A DIVISION OF BASIC PRODUCTS CORPORATION — HEVI-DUTY ELECTRIC COMPANY, MILWAUKEE 1, WISCONSIN

Write for new Bulletin 559 on vertical tube furnaces.

LIST NO. 239 ON INFO-COUPON PAGE 186

THERMOCOUPLES

PROTECTION TUBES
THERMOCOUPLE WIRES
LEAD WIRE
INSULATORS



PROMPT SHIPMENT from STOCK

REQUEST CATALOG and QUOTATION

ARKLAY S. RICHARDS CO., INC.
manufacturers since 1938
74 Winchester Street
NEWTON HIGHLANDS 61, MASS.

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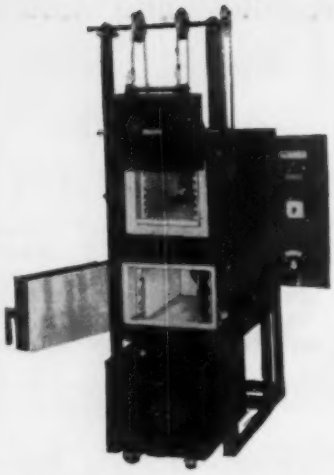


SAVE SPACE WITH A

SERIES 8055
COMBINATION MODEL

The Series 8055 is two electric heat treating furnaces (hardening 2000 and 2300° F., and drawing 800 and 1250° F.) in the floor space of one furnace. Each furnace is independently controlled permitting hardening and drawing operations to be performed at the same time. All models are delivered with separate controls for each furnace. The 8055 series is made in nine standard sizes . . . other models are made to your specifications. Furnaces operate on standard line voltage . . . no transformer necessary. A hardening and preheating combination is also available.

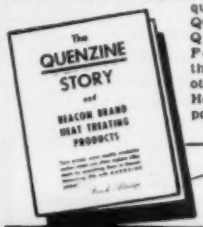
Write for a free catalog of the entire Lucifer line. Engineering advice is offered without obligation. Write, wire or call . . .

LUCIFER FURNACES, INC.
NESHAMINY 7, PENNA.
Phone: Diamond 3-0411

LIST NO. 122 ON INFO-COUPON PAGE 186

FREE
the QUENZINE STORY

Low priced, more readily available carbon steels can often repiace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .

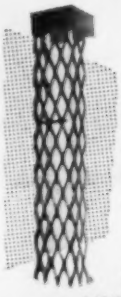


ALDRIDGE

ALDRIDGE INDUSTRIAL OILS, Inc.
3401 W. 140th St., Cleveland 11, Ohio

LIST NO. 100 ON INFO-COUPON PAGE 186

there's a *Glo*-QUARTZ* IMMERSION HEATER for Your Every Heating Requirement



- INSTANT HEATING
- SHOCK-PROOF
- AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE

Available from your Electroplating Distributor

WRITE FOR BULLETIN ▶

Glo-QUARTZ*
ELECTRIC HEATER CO., INC., Willoughby, Ohio
*Reg. U.S. Pat. Off. Phone: Willoughby 2-5521

LIST NO. 145 ON INFO-COUPON PAGE 186

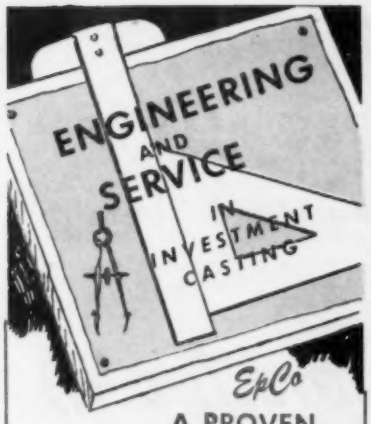
STANWOOD COR-WAL MUFFLES ASSURE LONGER SERVICE LIFE!

As with stacking baskets, carburizing boxes and retorts of Cor-Wal construction, developed by Stanwood, furnace muffles of Cor-Wal construction are giving outstanding performance—a longer service life—in actual use. Cor-Wal construction provides greater, long range resistance to thermal stresses and affords better load carrying factor. Several muffle designs are shown—others also available. Send for literature.

HEAT TREATING EQUIPMENT

STANWOOD CORPORATION
4817 W. CORTLAND STREET • CHICAGO 39, ILL.

LIST NO. 12 ON INFO-COUPON PAGE 186



EpCo

A PROVEN DEPENDABLE SOURCE

FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING Special Feature — Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.

ENGINEERED PRECISION CASTING CO.

MORGANVILLE, N. J.

LIST NO. 4 ON INFO-COUPON PAGE 186

Star Stainless screws have clean—bright—shiny—heads

STAR STAINLESS SCREW CO.

CORROSION RESISTANT

647 Union Blvd., Paterson 2, N. J.
Telephone: CLifford 6-2300
Direct N.Y. 'phone Wisconsin 7-6310
Direct Phila. 'phone WAlnut 5-3660

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MULTI MOTION DIES* . . . .

FOR TEST SPECIMENS . . .

DL-1001 TENSILE TEST BAR MPA STANDARD 10-51

- Tensile Bars
- Transverse Bars
- Green Strength
- Bushings
- Slugs
- Stepped Parts

Complete design facilities for dies or subpress units to press unusual shapes in lab presses.

*PATENTS PENDING

HALLER, INCORPORATED

16580 Northville Rd., Northville, Mich.

LIST NO. 149 ON INFO-COUPON PAGE 186

ECONOMY and PRECISION in POWDERED METAL PARTS by NORWALK

QUALITY CONTROL from blueprint to finished machine part. Specified strengths and tolerances are maintained from the first part to the millionth.

ECONOMY. Mass production brings the unit cost down for important savings.

SERVICE. Whether delivery requirements are routine or "emergency," we have the flexibility to meet your schedules.

DESIGN. Our Design Engineers employ powdered metallurgy at its maximum potential: to produce precision parts that do the job . . . with important economies in fabrication.

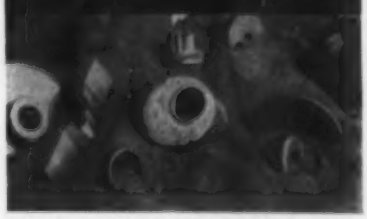
Submit your metal parts problems to us for study and suggestions *without obligation.*

FREE

Write for information folder, "Converting Powdered Metal into Machine Parts".

NORWALK POWDERED METALS, INC.

6 Muller Park, Norwalk, Conn.



LIST NO. 224 ON INFO-COUPON PAGE 186

PRINT-TO-PRODUCT SERVICE

How many of these steps does your product need?

If you can use skills and close tolerances like these, write for information to *Forge & Fittings Division, H. K. Porter Company, Inc., Cleveland 4, Ohio*

FORGINGS BY *Cleveland*

FROM A SINGLE SOURCE:

FORGINGS . . . Hammer, Press, Upset

MACHINING . . . Broaching, Milling, Turning, Drilling, Grinding

FINISHING . . . Heat Treating, Assembling, Painting, Plating

PORTER *FORGE & FITTINGS DIVISION*
H.K. PORTER COMPANY, INC.

PORTER SERVES INDUSTRY with 17 DIVISIONS including: Thermoid, Delta-Star Electric, National Electric, Riverside-Alloy Metal, Refractories, Connors Steel, Vulcan-Kidd Steel, Forge and Fittings, Disston, Leschen Wire Rope, Mouldings and H. K. Porter Company (Canada), Ltd.

LIST NO. 232 ON INFO-COUPON PAGE 186

Solve
Inspection
Sorting
Demagnetizing
Problems

with
MAGNETIC ANALYSIS...

MULTI-METHOD EQUIPMENT

Electronic equipment for non-destructive production inspection of steel bars, wire rod, and tubing. Detects mechanical faults and variations in composition and physical properties. Average inspection speed — 120 ft. per minute.

MULTI-FREQUENCY EQUIPMENT

An eddy current tester with six inspection methods operating simultaneously — for high-speed, non-destructive testing of non-ferrous and non-magnetic tubing, bars and wire from ⅛" to 3" diameter. Detects both surface and sub-surface flaws, and variations in chemical, physical and metallurgical properties at speeds of 200 to 600 ft./min.

WIRE ROPE EQUIPMENT

Electronic equipment for inspecting ferro-magnetic wire ropes from 1/32" to 3" diameter. Detects broken, cross-over or missing wires, plus defective welds and deformations at production speeds up to several hundred feet per minute.

COMPARATORS AND METAL TESTERS

Electronic instruments for production sorting of both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

DEMAGNETIZERS

Electrical equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

MAGNETISM DETECTORS

Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

"THE TEST TELLS"

For Details Write:

MAGNETIC ANALYSIS CORP.
42-44 Twelfth St., Long Island City 1, N. Y.

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All The Best

HEAT RESISTING ALLOYS

Ready When You Need Them

Please Send for Stock List and Literature

ROLLED ALLOYS, INC.
Heat and Corrosion Resistant Alloy Specialists

5309 Concord Avenue • Detroit 11, Michigan
Phone WAlnut 1-4462

330 William Street • South River, New Jersey
Phone CLifford 4-4616

LIST NO. 234 ON INFO-COUPON PAGE 186

more reproducible results with ultra-pure graphite shapes

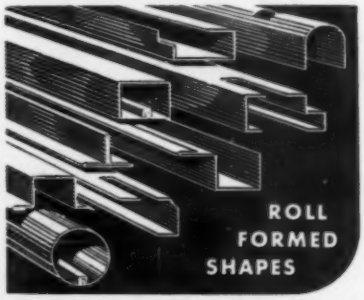
for:
METALLURGY
SEMICONDUCTOR PROCESSING
LABORATORY REACTIONS AND ANALYSES

The properties of United's new ultra pure graphites make them exceptional for crucibles, boats, funnels and similar parts. United offers you both stock and custom graphite shapes carefully machined, then purified by the famous "F" Process (developed by United, used by AEC). Your own processes are therefore more reliable, your results more reproducible.

Our R & D and technical service staffs are ready to serve you and can meet your "crash" delivery schedules. Write Dept. F for full details!

UNITED
CARBON PRODUCTS CO.
P.O. BOX 269, BAY CITY, MICHIGAN

LIST NO. 179 ON INFO-COUPON PAGE 186



Reduce your assembly problems and costs. Our shapes continuously formed, with high degree of accuracy, from ferrous or non-ferrous metals. Write for Catalog No. 1053.

ROLL FORMED PRODUCTS CO.

MAIN OFFICE AND PLANT
3761 OAKWOOD AVE. • YOUNGSTOWN, OHIO

LIST NO. 101 ON INFO-COUPON PAGE 186

GET A BID FROM

HOOVER

SPECIALISTS IN THE FIELD OF

Die Castings

SINCE 1922

Aluminum and Zinc

HOOVER

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio
In Canada—Hamilton, Ontario

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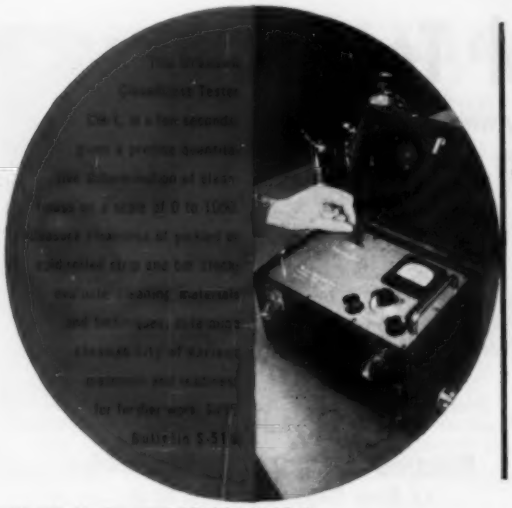


DO YOU KNOW...

HOW CLEAN IS CLEAN?

BRANSON ULTRASONIC CORPORATION
6 Brown House Rd., Stamford, Conn.

LIST NO. 241 ON INFO-COUPON PAGE 186

NEW pocket-size THICKNESS GAUGE

For flat or curved surfaces

only $75.00 F. O. B. Cleveland

Measures Nonmagnetic Coatings with ±5% ±.0001" accuracy

ELCOMETER measures thickness of porcelain enamel, paints, platings, foils, glass, paper, plastics, and other nonmagnetic coatings quickly and accurately. Gauges flat or curved surfaces and hard-to-get-at spots easily. Needle locking device assures correct reading every time. Complete with leather case containing inner pocket for test strips. Weighs only 6 oz. Completely self-contained.

WRITE FOR ILLUSTRATED FOLDER

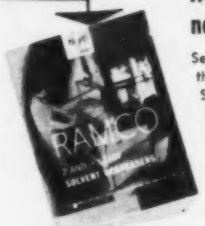
FERRO CORPORATION
4155 East 56th Street
Cleveland 5, Ohio

LIST NO. 148 ON INFO-COUPON PAGE 186

Q A

METAL PARTS CLEANING PROBLEMS?

Get the answers RIGHT from RAMCO'S new BULLETIN!



Send for your copy of the Ramco Bulletin. See how Ramco 2- and 3-dip degreasers can solve your metal parts cleaning problems, economically, efficiently, safely! *Write today!*

RAMCO EQUIPMENT CORP.
DIV. OF RANDALL MFG. CO., INC.
809 Edgewater Rd., New York 39, N.Y.

LIST NO. 128 ON INFO-COUPON PAGE 186

THE ULTRASONIC ATTENUATION COMPARATOR

The Sperry Attenuation Comparator for the measurement of ultrasonic attenuation and velocity comprises a complete transmission, detection and display system. Fields of application include determination of dynamic elastic moduli, investigation of mechanical deformation effects, evaluation of radiation damage, testing of ultrasonic transducers, networks and delay lines, and development of flaw detection and quality control techniques.

SPECIFICATIONS:
Frequency Range: 1 - 200 mc/sec.
Oscilloscope Sweep: 10 - 1,000 microseconds
Sweep Delay: 0 - 100 microseconds (calibrated)
Pulse Amplitude: Variable to 900 volts
Pulse Width: Adjustable 0.5, 1 and 2 microseconds
Exponential Attenuation Calibrator: 0.01 - 4db/microsecond
Oscilloscope: Integral 5-inch cathode ray tube display permitting simultaneous viewing of echo signals and exponential calibrator.

Sperry engineers are available for consultation. For further information, write . . .

Sperry Products, Inc.
Danbury, Connecticut

LIST NO. 206 ON INFO-COUPON PAGE 186

Our "combination" of quality products AND competent service assures you a quick knockout of your precious metals electroplating problems.

Technic inc ST 1-6100
P.O.BOX 965 PROVIDENCE 1 R.I.
7001 NO. CLARK ST. CHICAGO 26 ILL.

LIST NO. 237 ON INFO-COUPON PAGE 186

the GENUINE BRINELL

HARDNESS TESTING MACHINES made by the Alpha Co. of Sweden and available from our stock at New Rochelle

Never approached in ACCURACY AND CONSTANCY of calibration . . . at the standard 3000kg test load . . . maximum error plus or minus 2½ kg

Write for Bulletin No. A-18

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Testing Machines Division
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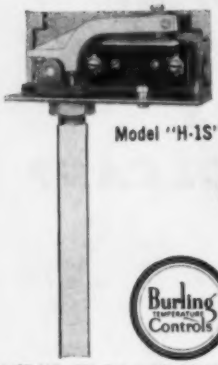

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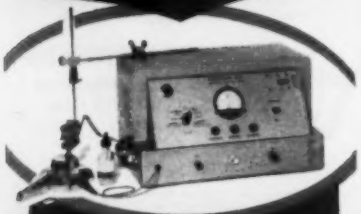

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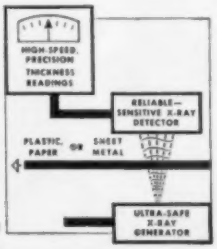

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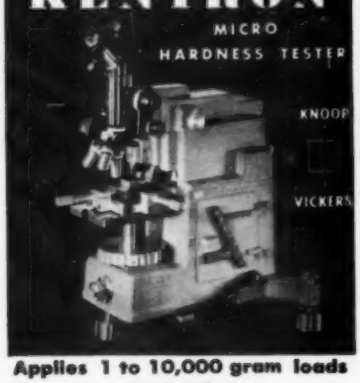

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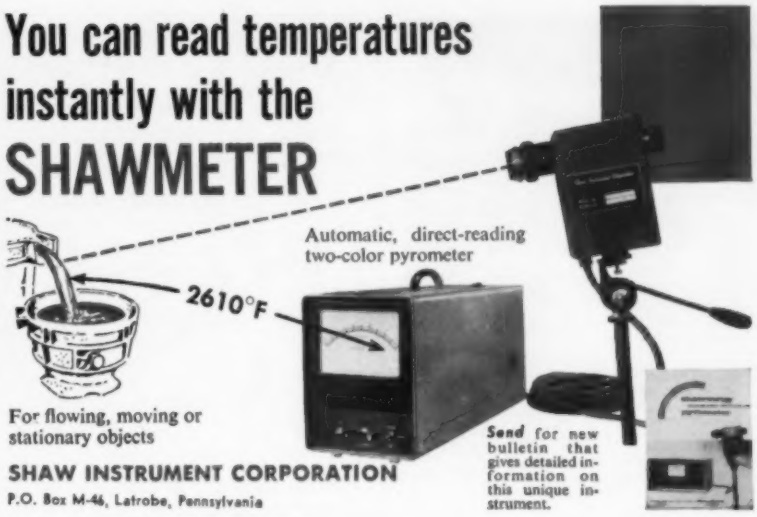

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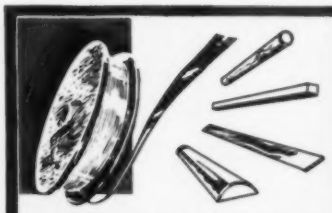

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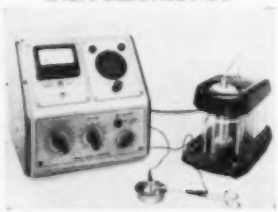

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USS "T-1" and TRI-TEN Steels cut dead weight—boost strength

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There are three of these 70-yard giants—all built by Marion Power Shovel Company. All achieve strength and toughness with least weight by the use of USS "T-1" Constructional Alloy Steel and USS TRI-TEN High-Strength Low-Alloy Steel.

Big Paul sets the pace at the Peabody Coal Company's River King mine near Freeburg, Illinois. It rams through rock and shale to uncover some two million tons of coal per year.

Since 1950, the art of big shovel making has increased dipper size from 35 to 45, 55, 60, and now 70 cubic yards per bite. Most of the buckets and dipper sticks of these giant shovels are made of USS "T-1" Steel, for otherwise, it would be almost impossible to make them light enough and tough enough. They hold up in this service, taking terrific impact abrasion and shock loading, even in the dead of winter. This is possible because USS "T-1" Steel retains its toughness at temperatures far below zero.

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◀ 70-yard dipper and handle, crowd rack, bail and sheave blocks—all built stronger and lighter with USS "T-1" Steel.

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Navy goes fission again

On this vertical boring mill at U. S. Steel's Homestead Plant, you see a forged steel flange that will serve aboard one of the Navy's new guided missile frigates. These are an entirely new class of naval vessel—their primary mission is the destruction of air targets and they are nuclear-powered.

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Many nuclear forgings like this one are made by U. S. Steel because here, the complete production is supervised and controlled by a team of forging experts. They melt the steel, pour the ingot, forge, heat treat and machine it. The very same team of USS Forging experts who made this flange will fill your order. We welcome your inquiries or requests for our free 8-page booklet about USS Nuclear Forgings. Write to United States Steel, 525 William Penn Place, Room 6031, Pittsburgh 30, Pa.

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USS

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L-160

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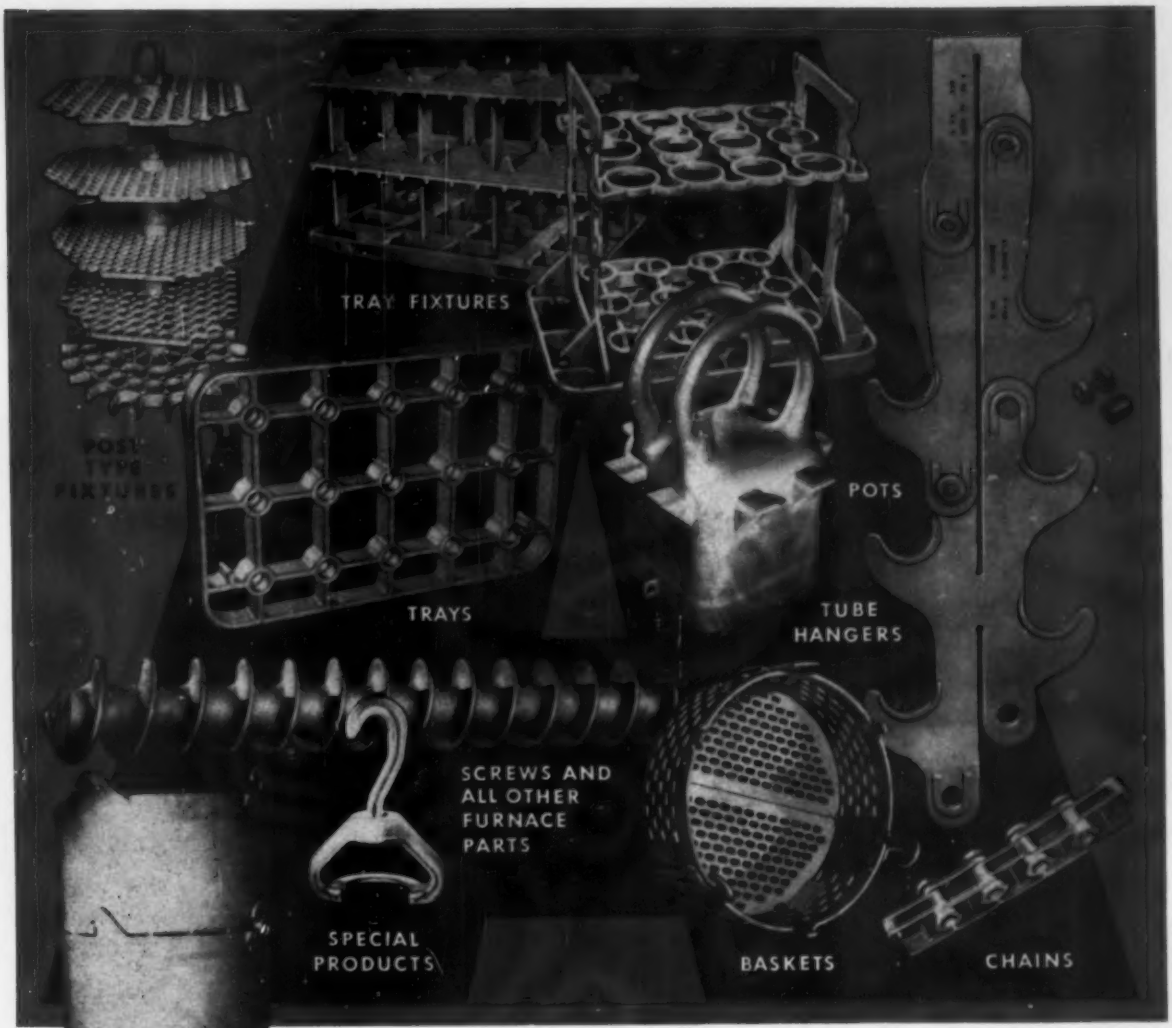

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Properties of Cr-Mn-N Steels

Digest of "The Tensile and Yield Strength of Cr-Mn-N Steels at Low Temperatures", by J. C. Shyne, F. W. Schaller, and V. F. Zackay, ⊜ Preprint No. 162, 1959.

THE EXTENSIVE cryogenic applications of metals in the past decade have resulted in considerable interest in the properties of pure metals and alloys at low temperatures. Austenitic structure and high strengths of the Cr-Mn-N steels have made them attractive for these possible applications. This paper presents the results of an investigation of the influence of nitrogen content and testing temperature upon the tensile properties of Cr-Mn-N steels.

Six steels were tested. The compositions were effectively constant with respect to substitutional solute elements and carbon. Nitrogen content varied from 0.06 to 0.49%. Hot worked bars were solution treated at 2000° F. and water quenched. Martensite content was determined after water quenching, after cooling to test temperature, and after fracture. Tensile tests were conducted at the following temperatures: —320, —256, —109, 73 and 212° F.

Typical test results from this investigation are represented in Fig. 1. The increase in strength of these alloys at the low temperature was accompanied by significant decrease of elongation and reduction in area. Extent of this ductility loss increases with increasing nitrogen content.

No appreciable amount of thermal martensite was found except in the 0.06% N steels which contained 9% after water quenching and 20% after cooling to —196° F. The amount of strain-induced martensite varied with nitrogen content and testing temperature in the following way:

1. In the range of 0.06 to 0.09%, the amount of strain-induced martensite formed ($\approx$ 90%) was essentially independent of nitrogen content and testing temperature (below room temperature).

2. With higher nitrogen contents the amount of martensite formed at any temperature decreased to a value of $< 5\%$ at 0.49% N. At any given nitrogen content, testing at —109° F. was found to produce the greatest

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—C. M. Carlisle, DIRECTOR OF ANALYTICAL CHEMISTRY

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"There you'll see how Jessop makes certain you get the exact per cent of alloying elements specified for your specialty steel.

"For example, you'll see a *microphotometer* — that's what I'm peering at so intently in the above photograph!

"I'm studying a film showing the spectrum of a sample of steel from Jessop's No. 2 electric arc furnace. Each chemical element in this specialty steel appears as a distinct line. By reading these lines, I can detect even minute *traces* of elements and after some simple calculations, determine the per cent of each."

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VMA 8719

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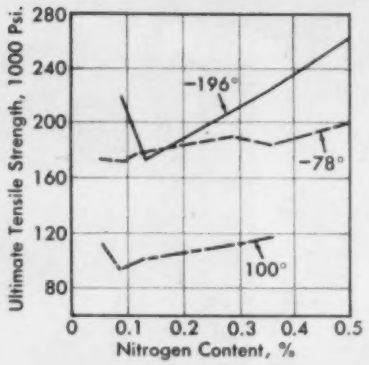
Cr-Mn-N Steels . . .

amount of strain-induced martensite.

The authors have interpreted their results in terms of two effects associated with the dissolved nitrogen. With increasing nitrogen content above 0.09%, the strength properties show a related increase, particularly at low temperatures. This is credited to interstitial solution hardening since a simultaneous decrease in the amount of strain-induced martensite



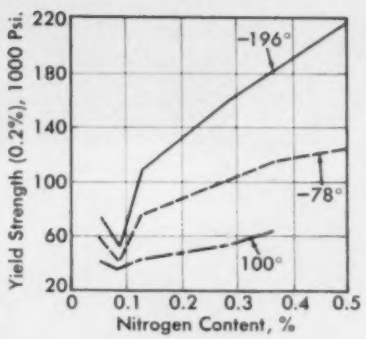


Fig. 1 — Mechanical Properties of Cr-Mn-N Steels With Varying Nitrogen at Several Test Temperatures

was observed. The reversal in the strength properties at nitrogen contents below 0.09% is credited to the strengthening effect of thermal martensite present, and the large amount of strain-induced martensite formed in these steels compared to those with higher nitrogen contents.

Despite the very attractive strength values obtained in these Cr-Mn-N steels at low temperatures, the associated drop in both elongation and reduction of area makes them generally unsuitable for cryogenic applications. W. R. UPTHEGROVE

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Hydrogen in Titanium

Digest of "Anomalous Effect of Hydrogen on the Mechanical Properties of Ti-8 Mn Alloy", by A. H. Fleitman, ⓜ Preprint No. 144, 1959.

THIS INVESTIGATION was undertaken to study the effect of hydrogen concentrations up to 450 ppm. on embrittlement of 8 Mn titanium alloy using different types of slow strain mechanical tests. Hot rolled, annealed and pickled sheet, 1/16 in. thick, was obtained from three different manufacturers. Specimens were tested in each condition:

1. As received.
2. After helium anneal at 1200° F. for 24 hr.
3. After vacuum anneal at 1200° F. for 24 hr. (hydrogen less than 30 ppm.)
4. Hydrogenized at each of four levels, 150, 225, 300 and 450 ppm. hydrogen, and held at 1200° F. for 24 hr.

Mechanical properties were determined at room temperature using

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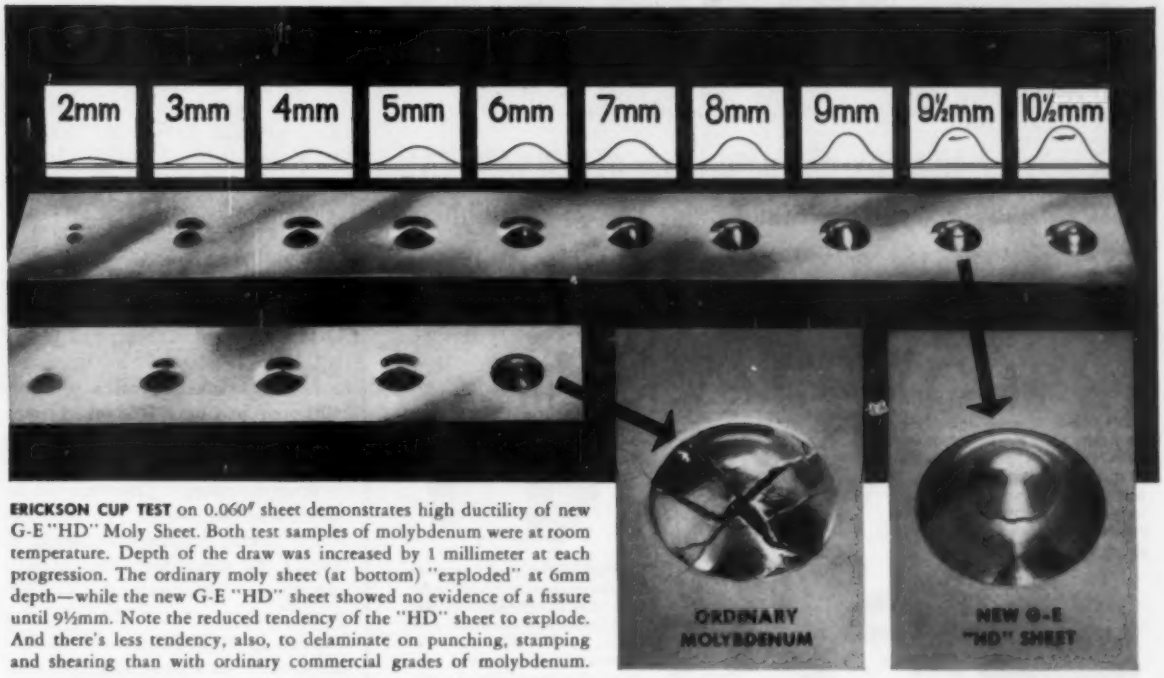

ERICKSON CUP TEST on 0.060″ sheet demonstrates high ductility of new G-E "HD" Moly Sheet. Both test samples of molybdenum were at room temperature. Depth of the draw was increased by 1 millimeter at each progression. The ordinary moly sheet (at bottom) "exploded" at 6mm depth—while the new G-E "HD" sheet showed no evidence of a fissure until 9½mm. Note the reduced tendency of the "HD" sheet to explode. And there's less tendency, also, to delaminate on punching, stamping and shearing than with ordinary commercial grades of molybdenum.

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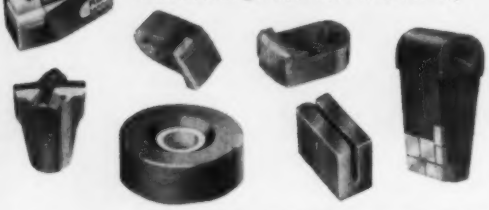

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Hydrogen in Ti . . .

notched and unnotched slow tensile tests, notched and unnotched tensile stress-rupture up to 1000 hr., and prestrained and aged unnotched tensile tests. The latter were performed on vacuum-annealed material containing 300 ppm. hydrogen.

To hydrogenate, test samples were heated to 1300° F. in vacuum. After adding a measured quantity of hydrogen, the samples were homogenized at 1300° F. for 4 hr. and held an additional 24 hr. at 1200° F. Hydrogen uniformly was good as indicated by hot vacuum extraction analysis, with values being within 10 ppm. of the intended levels of 150, 225 and 300 ppm.

No apparent brittleness (as indicated by elongation or reduction in area) was found in unnotched tensile specimens from any of the three vendors in specimens containing up to 450 ppm. hydrogen. Notched specimens showed a very slight increase in tensile strength with increasing hydrogen content. There was no indication of brittleness.

No brittle fractures occurred in any of the unnotched stress-rupture specimens containing up to 300 ppm. hydrogen, and the stress for rupture in 1000 hr. showed no decrease with increasing hydrogen content, all the hydrogenized specimens having ductilities comparable to the vacuum-annealed condition. The rupture stress in 1000 hr. for notched specimens generally showed a slight decrease with increasing hydrogen.

Unnotched tensile blanks in the vacuum-annealed condition and with 300 ppm. hydrogen were prestrained 5% in tension at room temperature, aged at 500° F. for 48 hr. and pulled in slow tension at room temperature. Strain rates of 0.025 and 0.0025 in. per min. were used. Data did not indicate hydrogen embrittlement.

The paper is in apparent disagreement with previous publications by R. I. Jaffee and co-workers at Battelle Memorial Institute which presented data indicating severe embrittlement in 8 Mn titanium alloy with hydrogen as low as 200 to 250 ppm. The Battelle work was carried out on subsize round tensile specimens, ⅛ in. diameter and ¾ in. gage length, and the material was hydrogenized before fabrication was completed. In contrast, this research

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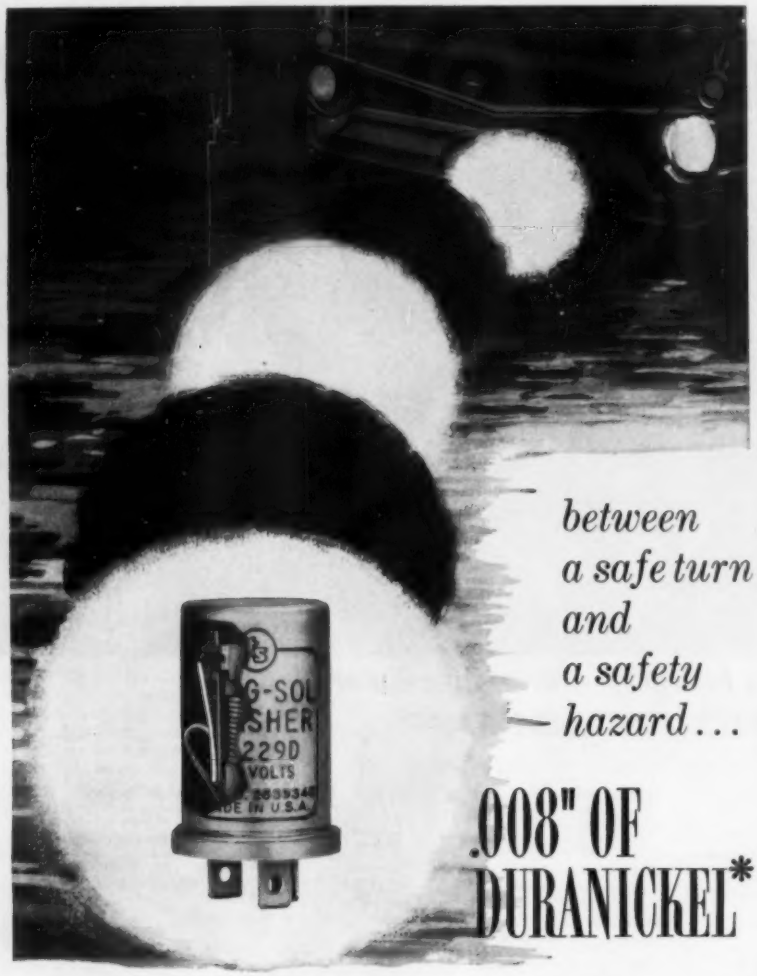

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Hydrogen in Ti . . .

was performed on 8 Mn titanium alloy sheet specimens that were not hot worked after hydrogenizing. Some possible explanations for the drastically different results are given. It is theorized that the anomalous results occurred because the transition temperature for the hydrogenized 8 Mn titanium alloy specimens in this work was below room temperature.

W. R. OPIE

The Importance of Directionality in Drawing Quality Sheet Steel

Digest of "The Importance of Directionality in Drawing Quality Sheet Steel", by R. L. Whitely, ● Reprint No. 174, 1959.

DIRECTIONALITY in drawing quality sheet steels is usually considered in a two-dimensional sense as indicated by differences in properties measured in the plane of the sheet. Directionality, however, is a three-dimensional effect. Consequently, properties measured in a direction perpendicular to the sheet plane might be different than those measured in the plane. Unlike planar directionality, normal directionality can be beneficial to the press performance of the material.

Tensile specimens of sheet material on plastic deformation often exhibit different amounts of strain in their width and thickness dimensions. The ratio of width and thickness strains measured at any strain level is called R. If R is measured in several directions in the sheet, an indication of both the planar and normal components of directionality can be obtained. Planar directionality is indicated by a difference in R in the different directions, while the normal directionality is indicated by the average value of R. A completely isotropic material would have a value of R equal to one in all directions. A material with an average value of R greater than one would be generally more resistant to thinning and puckering during forming than a perfectly isotropic material. Such a material should be desirable for practically all drawing operations.

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Drawing Sheet Steel . . .

It was originally thought that high values for R showed better press performance where the draw was unsymmetrical in nature, and that this beneficial effect would not prevail for a symmetrical drawing operation. This paper shows that a relationship between drawability and directionality for a symmetrical drawing operation does exist.

The experimental work was designed to evaluate the drawability of several materials with widely varying properties and directionality. The purpose was to determine the relative effect of directionality and other properties upon drawability. Sixteen low-carbon steels (eight rimmed and eight aluminum-killed), two stainless steels, two aluminum alloys, commercial pure copper and 65-35 brass were tested. These materials ranged in yield strength from 5000 to 45,000 psi., and in total elongation from 25 to 50%. The average strain ratio R ranged from 0.6 to 1.6, indicating a considerable degree of normal directionality in certain materials. The stainless steels and nonferrous metals were all commercially processed, but some of the low-carbon steels were specially treated to attain a greater range of properties than ordinarily encountered commercially.

The drawability of each material was evaluated by determining the largest blank of the material which could be successfully drawn into a 2-in. flat-bottomed cup like that shown in Fig. 1. The procedure followed was to draw successive blanks of increasing diameters until the blanks failed to draw. The drawability of the material was then expressed as the ratio of D, the diameter of the largest blank successfully drawn, to d, the diameter of the drawn cup. (For this experiment, d equaled 2 in.) The ratio D/d is called the drawing ratio.

Fig. 1 — Initial Test Blank and Final Cups Formed in a Successful and an Unsuccessful Cup Drawing Test. Earing of the successfully formed cup is a result of the planar directionality of the material

The directionality of each material was determined by measuring the strain ratio, R, at different angles to the rolling direction. This was done by measuring the longitudinal and width strains of a ¾-in. wide specimen with parallel sides. It was elongated about 20%. The strain ratio, R, was then calculated from these values of width and length strains.

In general, the aluminum-killed steels showed the best drawabilities, while the stainless steels and nonferrous metals had the poorest. Although most of the materials produced "ears" when drawn, the occurrence of "earing" did not appear to affect the relative drawability of the materials. (*Cont'd. on p.* 206)

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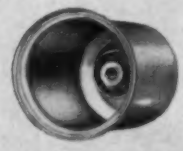

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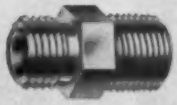

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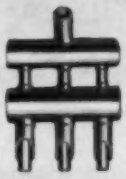

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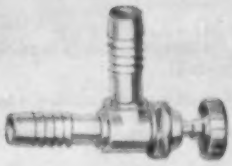

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Drawing Sheet Steel . . .

On the basis of measured R values, none of the materials were perfectly isotropic. Figure 2 shows the directional variation in R for three low-carbon steels; these variations are considered to be typical of those found in almost any box-annealed low-carbon steel.

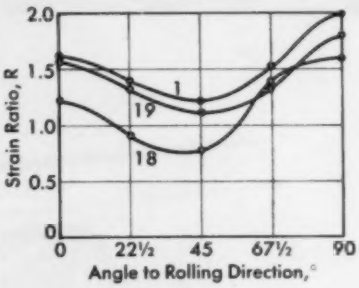


Fig. 2 — Typical Directional Variation of the Strain Ratio, R, Observed in All the Low-Carbon Steels Tested. Steels 1 and 19 are drawing quality aluminum-killed steels while steel 18 is a drawing quality rimmed steel

The correspondence between "earing" and directional variations in R was quite good; the height of the ears produced generally varied according to the degree of fluctuation in R. In almost all tests, the "ears"

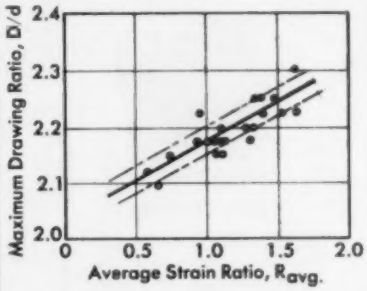
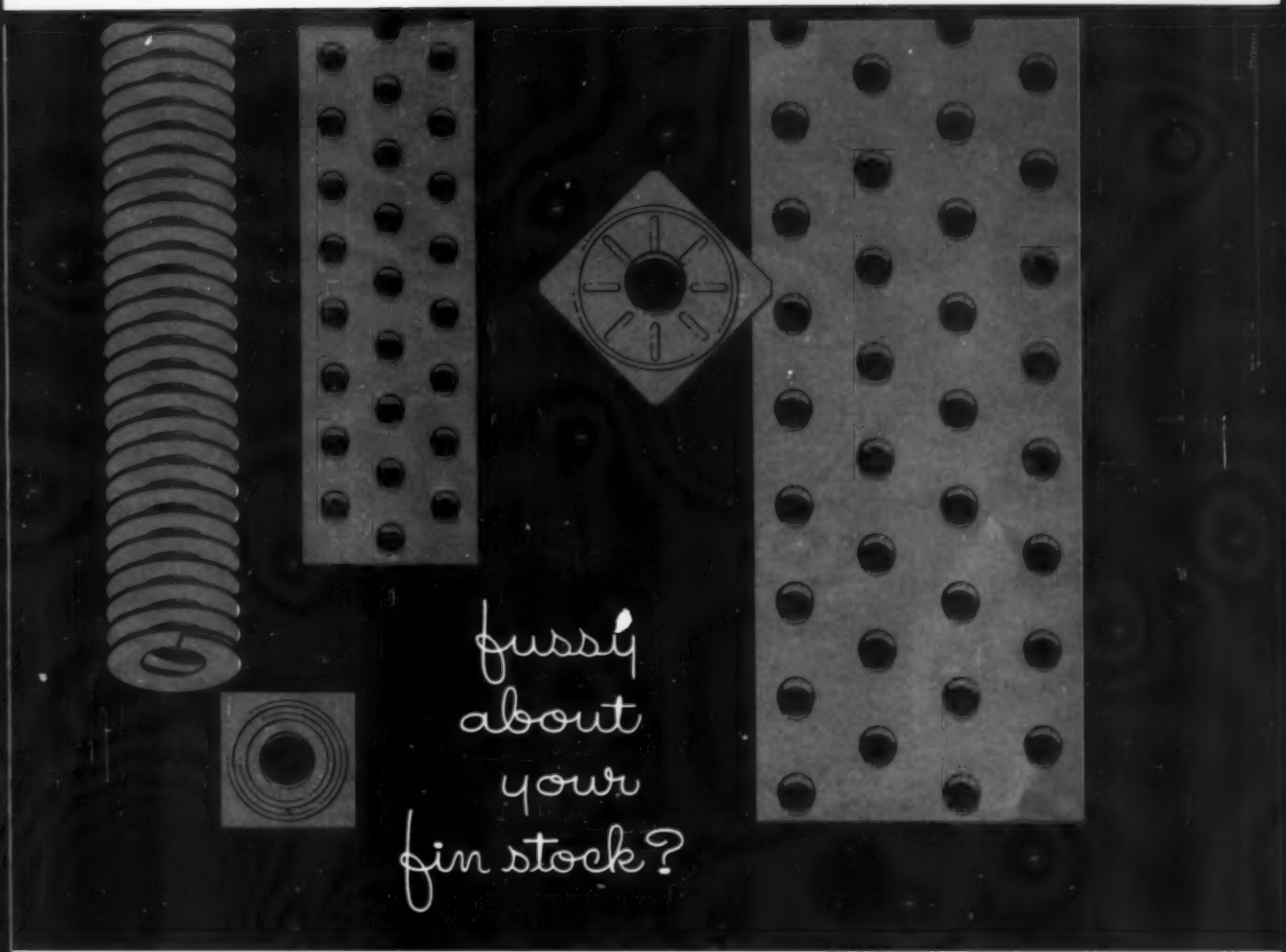


Fig. 3 — Effect of the Average Strain Ratio, $R_{avg.}$, on the Maximum Drawing Ratio, D/d. Dashed lines represent limits of experimental error

formed in the direction in which R was a maximum.

Figure 3 shows the relationship between drawing ratios and the average strain ratios of the materials.

(*Continued on p. 210*)



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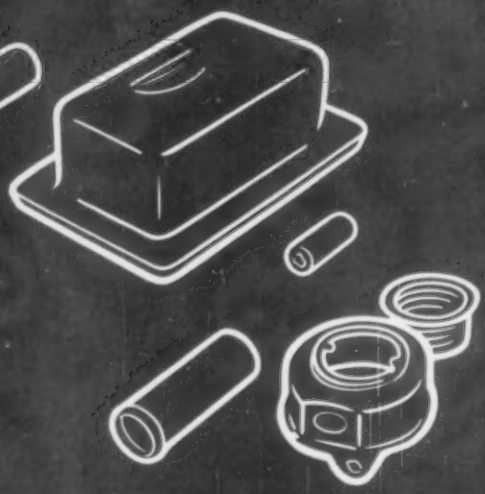

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Drawing Sheet Steel . . .

While the data show considerable scatter, a definite relationship exists betwen drawability (drawing ratio, D/d), and normal directionality (average strain ratio, $R_{avg.}$). In fact the only single property to show a significant relationship to drawability was the average strain ratio or the normal directionality of the material.

Directionality is an important property of drawing quality steels not always detrimental to press performance. While planar directionality is usually objectionable, normal directionality is desirable for good drawability even in symmetrical drawing operations. The general superiority of aluminum-killed steels over rimmed steels for deep drawing applications can be attributed to the greater normal directionality of the aluminum-killed steels.

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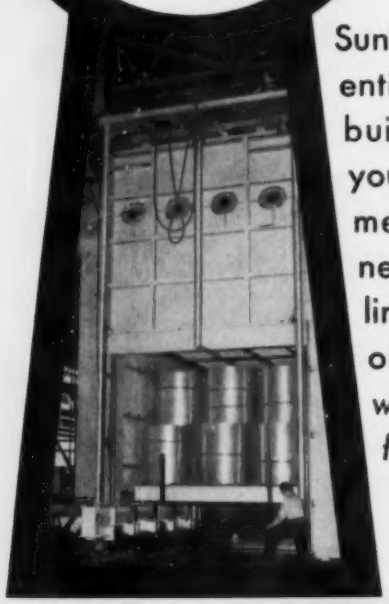

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Copper in Low-Carbon Steels

Digest of "Tensile Properties of Copper-Bearing Low-Carbon Steel", by G. W. Bush and R. W. Lindsay, Preprint No. 140, 1959.

THE ADVANTAGES and disadvantages of copper as an alloying element in steel are generally rather well understood. However, there is an absence of information as to whether or not there is a limiting content of copper below which the element has little, if any, effect on mechanical properties. Because residual copper, in amounts of 0.1% or more, is not uncommon in commercial steels, it is important to know the effects of small quantities of copper on the properties of steel. This is especially true for deep drawn steels where slight changes in properties may cause differences in the drawability of the material.

In the present work, the effects of residual copper on the tensile properties of a deep drawn, low-carbon grade were studied by standard tensile and true stress-true strain tests. The effects of varying copper contents on crystallographic orientation were studied by torque magnetometer tests. With an induction furnace, 100-lb. heats of a rimming-type steel were produced. Varying amounts of copper were added to produce five copper levels between 0 and about 0.50% Cu. (Actual copper contents were 0.002%, 0.12%, 0.18%, 0.28% and 0.48%). The ingots were processed by "mill practice" to cold rolled, box-annealed, deep drawn sheets 0.040 in. thick. Since no mention is made in the paper of temper rolling, it must be assumed that the test results reported represent the dead-soft condition, and, in this respect, the tensile properties differ somewhat from those normally reported for commercial material.

When the tensile data were plotted against weight percent copper, there was virtually no change in such properties as yield point, tensile strength, fracture strength, strength coefficient, elongation, or work hardening modulus between 0.002 and 0.12% Cu. At higher copper levels, the tensile strength, fracture strength, and strength coefficient increased continuously with

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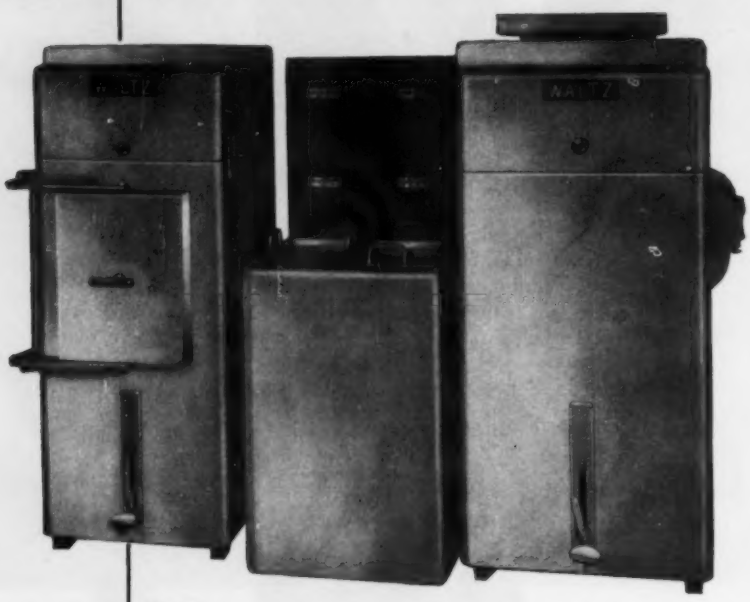

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Low-Carbon Steels . . .

increasing copper. A minimum value in the yield-point data was observed at about 0.3% Cu, but tensile elongation and work hardening modulus decreased with increasing copper. From these results, it is concluded that there is a copper content below which the mechanical properties of a steel (of the base analysis used) are not affected. It is further concluded that this content lies between 0.1 and 0.2% Cu.

In the torque magnetometer test, the steels with 0.002 and 0.12% Cu exhibited a high degree of anisotropy; at higher copper contents, a lower degree of anisotropy was observed. The effect of these apparent changes in crystallographic orientation on deep drawing properties was not determined. However, other work has shown that, in drawing certain asymmetrical shapes, material with a high degree of anisotropy frequently performs better than material with low anisotropy.

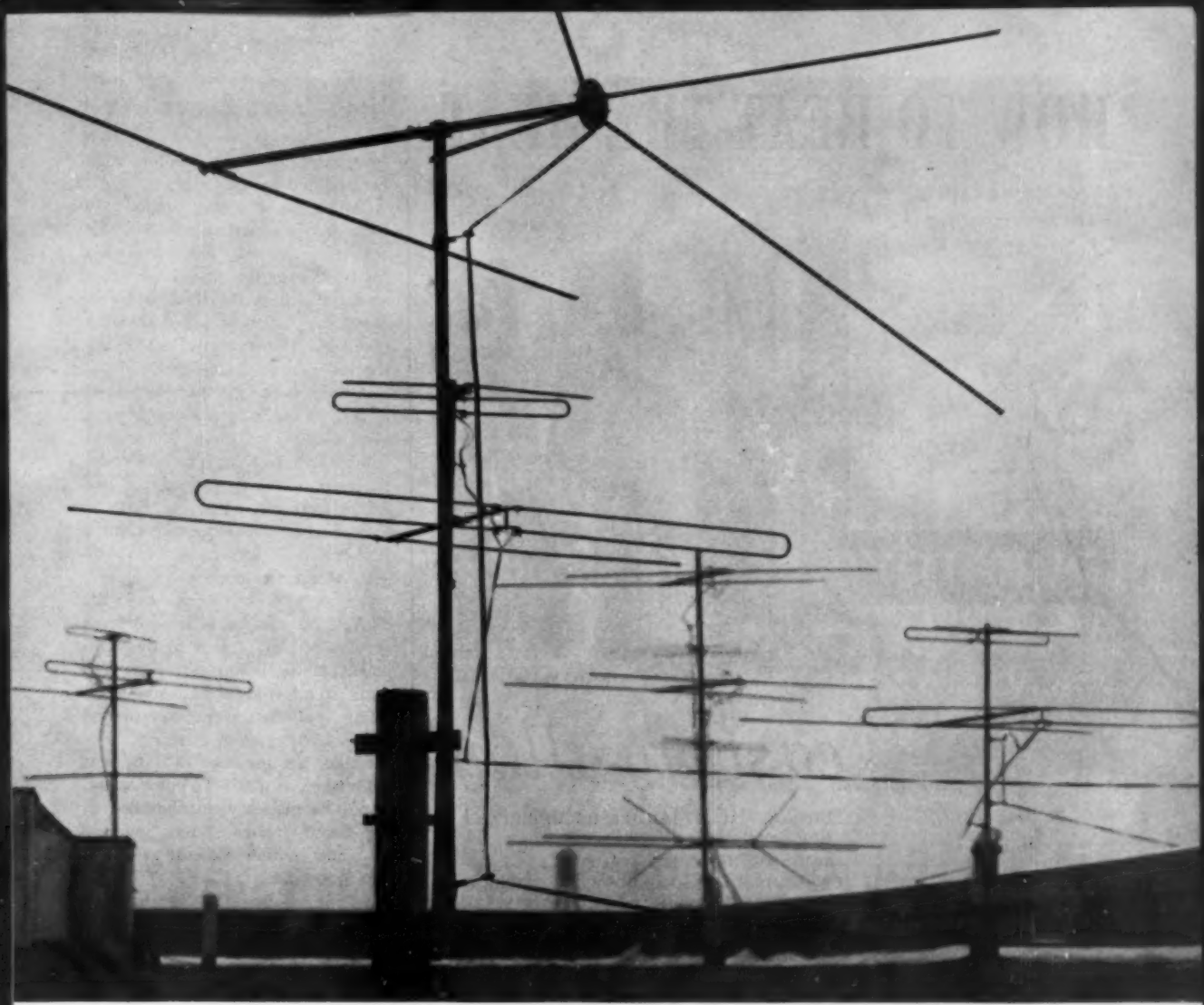
The data obtained in this work are admittedly limited and the authors acknowledge that the results cannot be generalized as a quantitative evaluation of the effect of copper on the drawability of low-carbon, deep drawn grades of steel. However, on the basis of the assumption that certain mechanical properties can be used as a qualitative measure of drawability, the authors conclude that the drawability of sheet steel should not be affected by less than 0.1% Cu. It seems likely to this reviewer that other investigators, by statistical treatment of large amounts of practical data (for example, PARC analysis), might be able to find reason to question this conclusion.

G. H. ENZIAN

High Boron Alloys

Digest of "An Exploration of High Boron Alloys", by A. U. Seybolt, Preprint No. 135, 1959.

THIS INVESTIGATION was undertaken to test high-boron alloys as high-temperature structural material. In view of boron's high melting temperature (about 4000° F.), low density (about 2.3 g. per cc), and potentially high strength (hardness, Vickers 2800), it was hoped that the



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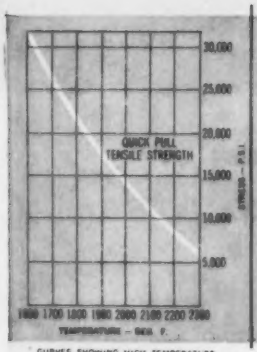

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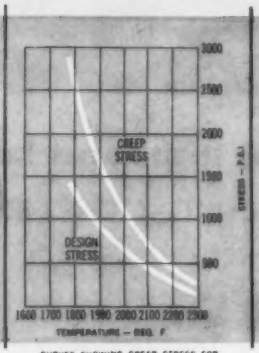

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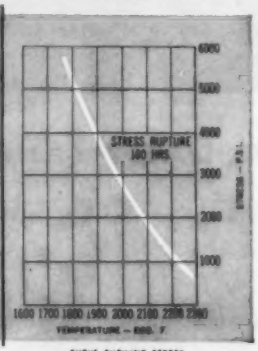

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High-Boron Alloys . . .

inherent brittleness of boron might be modified by alloying.

Boron has a strong tendency to form borides, particularly with the transition metals. The boron used for these experiments was produced at Battelle Memorial Institute by decomposing BBr_3 on a hot tantalum filament. Purity was about 99.9%, the chief impurity being 0.05% C.

Alloys of boron containing up to 6 at.% of gallium, yttrium, cerium, silicon, tin, titanium, zirconium, columbium, tantalum, molybdenum, tungsten, rhenium, iron, nickel and cobalt were melted as 1-g. heats in a vacuum induction furnace using a BN crucible. Pressures were usually 0.1 micron or lower.

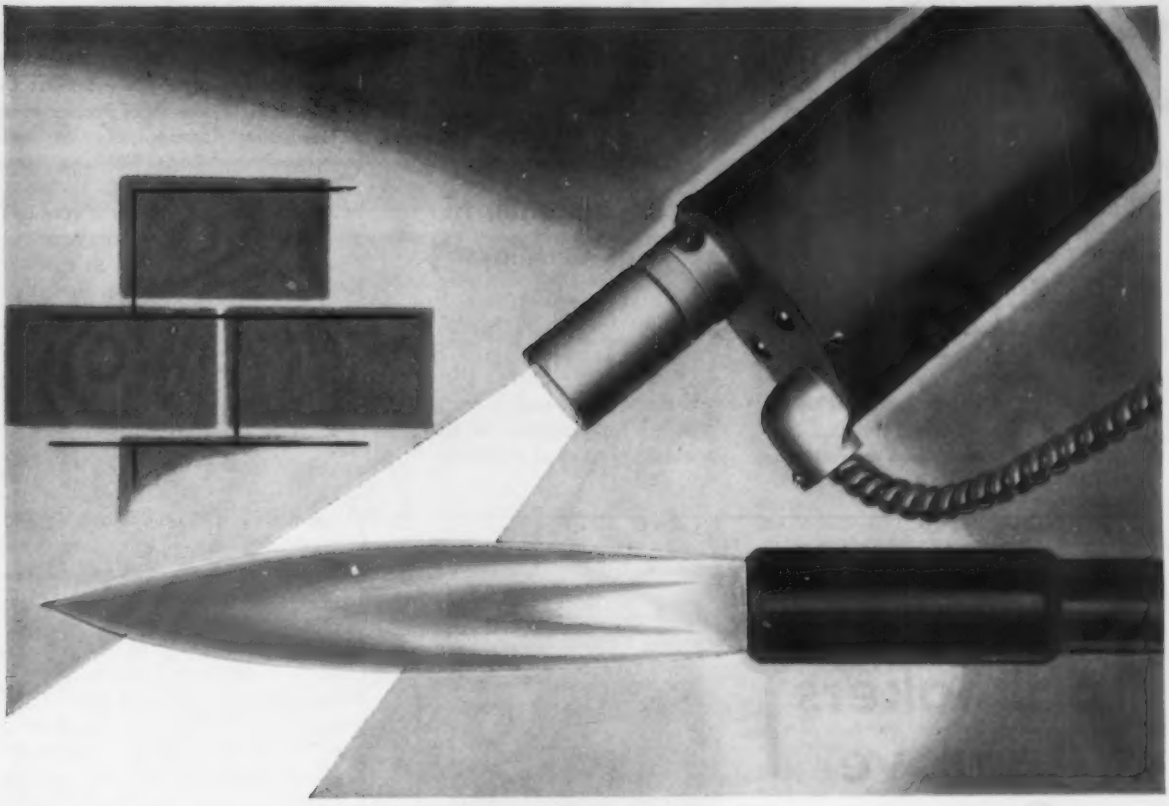
Attempts to identify phases in the alloys by X-ray diffraction were not very successful because of the complexity of the boron diffraction pattern. In a few instances, some interesting patterns were determined with a fair degree of accuracy. For example, the presence of TiB_2 was established in a 6% Ti boron alloy. Also, two phases were identified in the boron-yttrium system, namely BY_{12} and another phase of unknown composition near 1 at.% Y. The latter phase has the approximate composition YB_{50}, with close to 1700 atoms in the unit cell.

Metallography and hot hardness were found to be the most useful tools for evaluating these alloys. Mechanical tests were not practical because of the brittleness problem. In most of the alloys, a second phase was observable without etching, but where etching was desirable a $1HF\text{-}1HNO_3\text{-}2H_2O$ solution was used.

The pure boron showed no indication of a second phase. Grain structure and twins were readily visible with polarized light. All the alloy systems examined had intermediate phases and all alloys were brittle. Several alloying elements (titanium, zirconium, molybdenum, iron, cobalt and nickel) were found to have appreciable solid solubility in boron of the order of 1 at.%.

Boron cylinders with good density could be hot pressed from the pure powder. However, this technique was difficult to apply, and was unsuccessful in producing useful specimens for any mechanical tests.

(*Continued on p.* 216)



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High-Boron Alloys . . .

Hot pressing at very high pressures (up to 50,000 atmospheres) and high temperatures (up to about 4500° F.) was applied to make several boron alloys. It was hoped that very high temperatures and pressures might stabilize some new boron phase. The compacts made by this technique were brittle and contained no new phase.

Hot hardness tests revealed that several alloys had much higher hardnesses between room temperature and 1650° F., than unalloyed boron. In this respect, alloys containing titanium, zirconium and molybdenum were of greatest interest. There is little doubt that such alloys would have great potential in the high-temperature field if some slight ductility were present.

P. D. FROST

Precipitation In Cu-Cr Alloys

Digest of "Precipitation Process in Copper-Chromium Alloys", by R. O. Williams, Preprint No. 136, 1959.

THIS PAPER represents an experimental investigation of the precipitation process of chromium from supersaturated copper alloys at 400 and 500° C. (750 and 930° F.), as related to a theory of precipitation strengthening recently proposed by the author ("Theory of Precipitation Hardening: Isotropically Strained System", by R. O. Williams, *Acta Metallurgica*, Vol. 4, 1957, p. 385). This particular system is of considerable interest since copper alloys with more than 0.1% Cr can be made to precipitation harden so that they achieve high strength while retaining high electrical conductivity.

The experimental phase of the work involved solution treatment of a series of copper alloys containing from 0 to 1.33% Cr, quenched from about 1050° C. (1920° F.), then aged over a range of times at 400 and 500° C. (750 and 930° F.). The aged and aging specimens were studied by X-ray diffraction, dilatometer measurements, and tensile property determinations.

The greater part of the paper is given to an analysis and interpretation of the experimental data. Limitations to the experimental accuracy and available methods in an investigation of this type are such that the accuracy of any conclusion cannot be demonstrated with certainty by a single experiment or even a reasonable combination of experiments. However, the author has presented an analysis of his observed data, as well as that of other investigators, which is sufficiently logical to provide an explanation meriting consideration and continued investigation, but, at the same time, sufficiently speculative that it will probably provoke challenge and lively discussion.

The data present evidence that the aging consists of two essentially distinct processes. The first process, which represents the actual precipitation of chromium, involves changes in the properties most sensitive to chromium in solid solution. These result particularly from the presence and effects of excess vacancies, and show an apparent activation energy based on that for vacancy diffusion. The second stage can then involve competitive particle growth, loss of coherency or phase changes or both. The experimental data indicate the probability of competitive particle growth. There is also a possibility one or both of the other processes occurs at the same time.

The form of the precipitated chromium is a distinct problem which is

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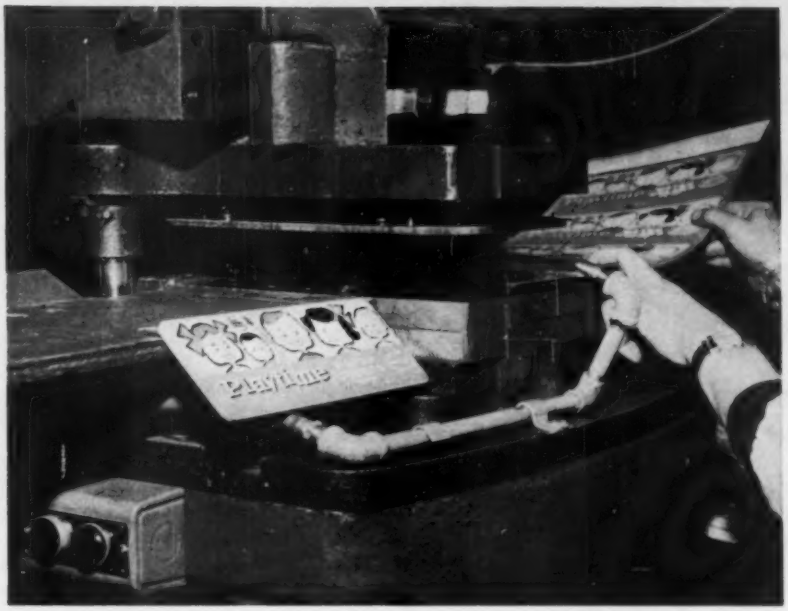

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The manufacturer, Sobel Metal Products Co., Easton, Pa., talked it over with his local Bethlehem tool steel distributor, Luria Steel Supply Co., Catasauqua, Pa. The Luria representative proposed the use of Lehigh H for the die, and Brake Die for the punch. This proved a wise choice, for combined, the two tool steel grades turned out 150,000 pieces without any need for redressing. And the black plate received nary a scratch.

Bethlehem Lehigh H (AISI D-2) is our easy machining high-carbon, high-chrome tool steel. It is an air-hardening grade, with plenty of wear-resistance thanks to its excellent carbide distribution. Brake Die, a grade of special analysis steel, is oil quenched and tempered to develop the mechanical properties needed for maximum wear and toughness.

Bethlehem regularly produces about 30 different grades of tool steel—a range so wide as to meet virtually every requirement. For full information, call your Bethlehem tool steel distributor.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Hot-Work Tools Last Longer When Thermal Stress Is Reduced

Deterioration of hot-work tools in service by heat checking or cracking depends largely on the severity of thermal stress developed in service. Anything which can be done to decrease the magnitude of the thermal stress will increase the service life of the tools.

One of the most essential steps in using hot-work tools is to preheat them to their normal working temperature before use. This seemingly insignificant step will often improve the tool life appreciably because it decreases the severity of the initial stress cycles.

The provision of multiple tools which are used in succession is another simple way to decrease thermal stresses on certain types of hot-work tools. For example, on piercing operations the press may be provided with as many as six piercing punches mounted on an indexing fixture. After each piercing operation a different punch is moved into position for the next operation. This permits each punch to cool during the time of the next five operations, greatly reducing the severity of thermal stress. The service life of punches used in this manner is often twice that of punches used continuously in the same operation.

Air-4 hardens in air at 1550F.

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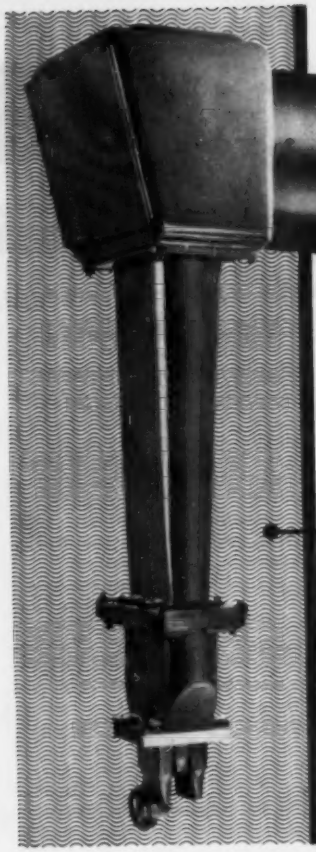

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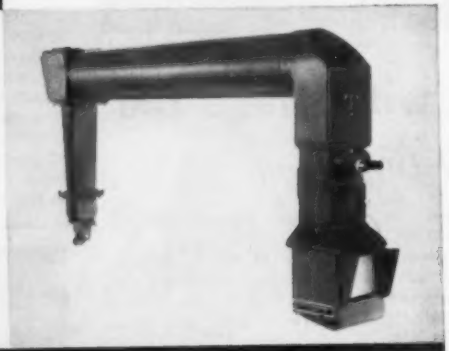

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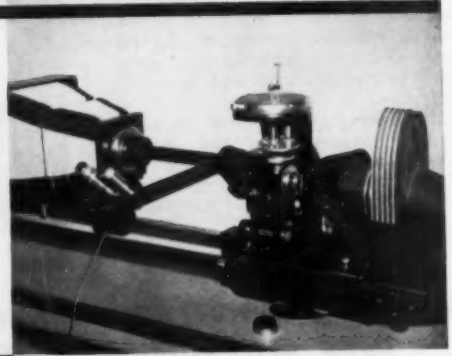

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Write for Manual D-287, containing specifications, technical data and photographs. Bausch & Lomb Optical Co., 84946 St. Paul Street, Rochester 2, New York.

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Cu-Cr Alloys . . .

not completely answered by the experimental data. However, a nucleus of a metastable form of face-centered cubic chromium presents an attractive possibility to explain nucleation by the precipitation of extremely fine particles coherent with the parent matrix. The author takes the diffuse X-ray effects, consisting of diffuse rods in the <111> directions around each reciprocal lattice point, to mean that the precipitate consists of coherent plates on the {111} planes of the copper.

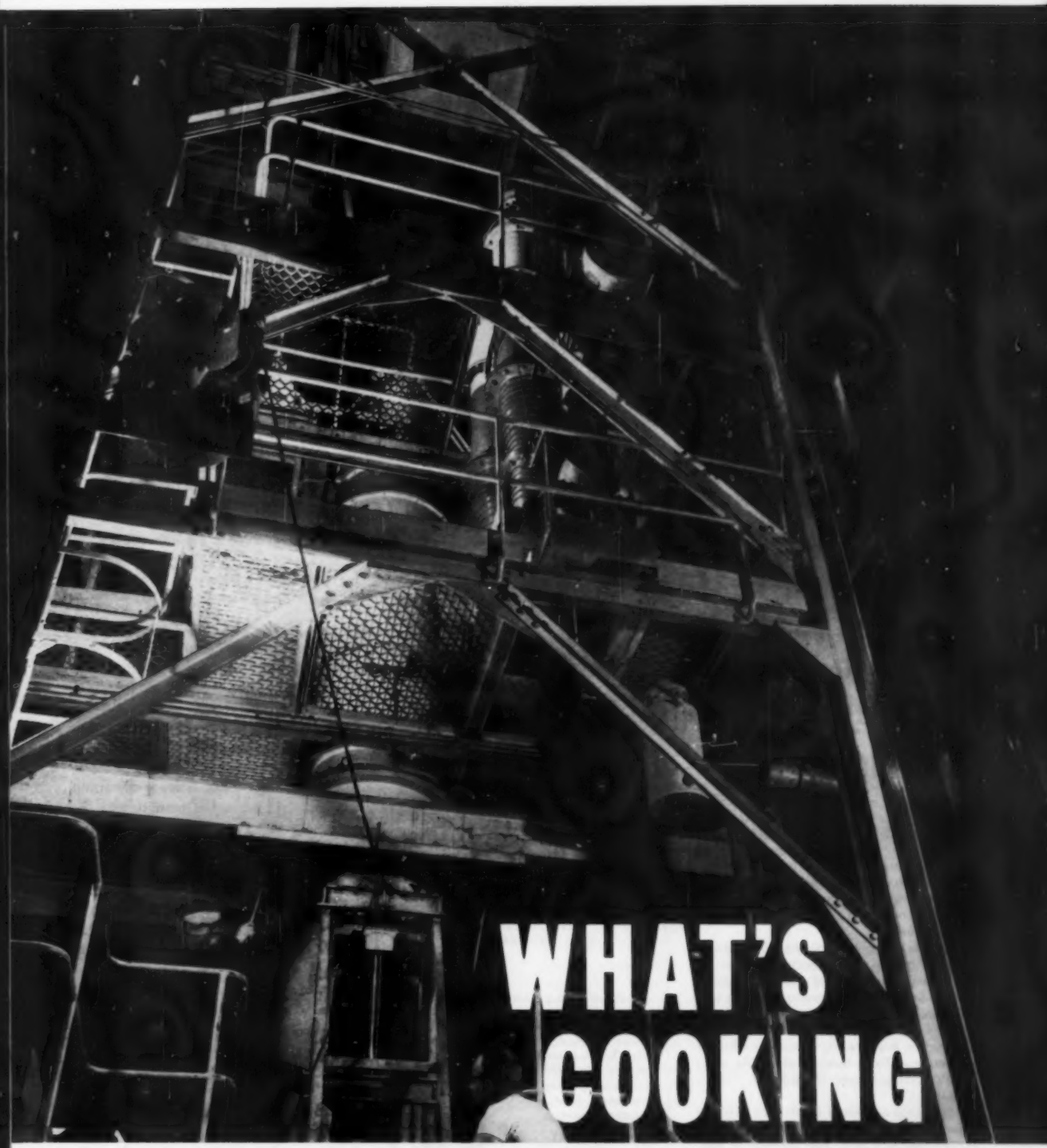
The author interprets his own data, as well as that of others, to be consistent with the requirements of his theory of precipitation hardening where the matrix and particles are hydrostatically stressed to a common lattice parameter. The apparently homogeneous nucleation, based on the very large number of extremely small particles, fits this concept.

The system studied appears to be unique in that the diffuse effects arise not from the diffraction power of the precipitate, but from the displacements produced in the matrix by the precipitate. E. C. MILLER

Grain Structures at High Temperatures

Digest of "Directional Grain Structures for High-Temperature Strength", by F. L. VerSnyder and R. W. Guard, Preprint No. 168, 1959.

DEFORMATION and fracture characteristics of metals and alloys at elevated temperatures are influenced by the nature of their grain boundaries, and fracture at high temperatures usually propagates along grain boundaries. In this paper, the authors demonstrate experimentally that the tendency toward intergranular fracture can be reduced by using a directional grain structure wherein the grains are elongated in the direction of the stress axis. The experiments were performed on a 75% Ni, 21% Cr, 3.5% Al alloy casting which is known to have a low tensile and rupture ductility (< 2%) and a large tendency toward intercrystalline cracking, when the grain structure is equiaxed. The directional or columnar structure was



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WRITE for Bulletin 4-25.

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Grain Structures . . .

obtained by casting in a special mold which provided a temperature gradient along the height of the casting. Grains were obtained with width-to-length ratios of 1:5 to 1:25.

The results of creep rupture tests (1472 to 1652° F.) in directions parallel and normal to the long axes of the grains are summarized in Fig. 1, in comparison with values obtained in equiaxed-grain specimens.

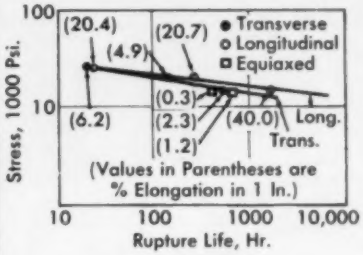

Fig. 1 — Results of Creep Rupture Tests

The fracture resistance as indicated by the rupture ductility and the time to the end of the second stage of creep was greatest for the longitudinal structure and less for the transverse and equiaxed structures. By having the grains extending parallel to the applied stress, the rupture ductility was increased by a factor of 4 to 10, and the rupture strength by 15 to 20%. The authors believe the improvement occurs because the longitudinal grain structure inhibits the normal intergranular mode of fracture, so that fracture must become predominantly transgranular.

The creep resistance of longitudinal and transverse specimens was the same during the early part of the creep curve, and the equiaxed grain specimens had a higher resistance to creep deformation but a lower resistance to fracture than the columnar structures. These results, coupled with observations on the modes of fracture of specimens with various orientations of the columnar grain axes with respect to the stress axis, lead the authors to conclude that the creep rupture properties of directional grain structures are primarily related to the directionality of the grain boundaries and not to the preferred orientations of the grains.

H. H. Chiswik

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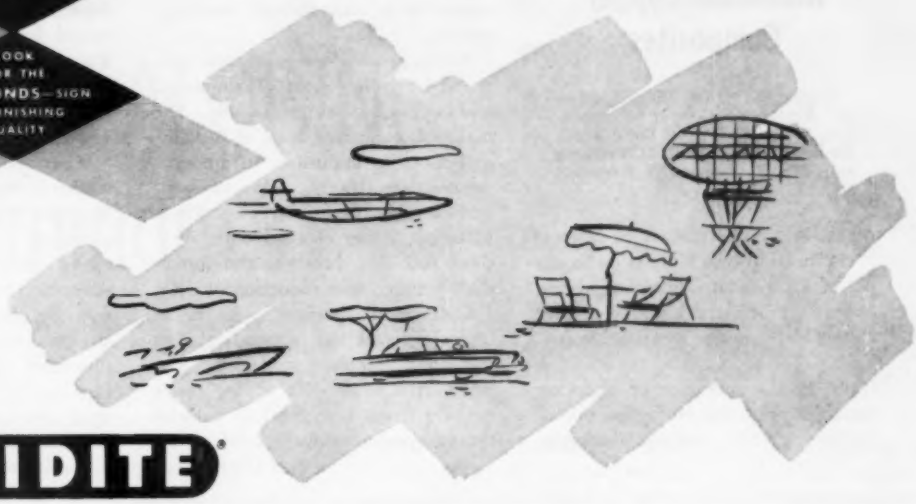

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Aluminum-Copper Composites

Digest of "An Investigation of Aluminum-Copper Composites Prepared by Solid-State Bonding", by J. M. Williams and M. B. Bever, ⊕ Preprint No. 175, 1959.

SOLID-STATE BONDING is of interest to metallurgists both as an example of a solid-state diffusion process and as a practical technique to clad metals and produce metal laminates. This paper reports the results of a study of the influence of sintering variables upon the strengths, microhardness profiles, and metallography of aluminum - copper composites made by a conventional two-stage process.

Green bonded compacts were prepared by rolling bars of aluminum and copper together as a pack. The materials contained none of the normal metallic impurities in amounts greater than 0.003%. Two different surface conditions were studied. Material A was cleaned with abrasives and wire brushes, and immediately rolled to a reduction of 64%.

Cylindrical specimens, 1 in. in diameter, were cut perpendicular to the bond interface and were sintered at 350 or 400° F. for times ranging from 4 to 96 hr. Special tensile specimens were used to insure that failure occurred at the interface. Six to 18 specimens were tested for each sintering condition. Excessively low strength values which were obviously associated with incomplete bonding over the interface were discarded.

The results of these tests are shown in Fig. 1. Variables involved are the temperature and time of sintering, and the time elapsed between cleaning and rolling. The difference in reduction during rolling was significant. The lower green strength exhibited by material B illustrates the adverse effect of surface contamination (oxide formation) upon bonding. The authors attribute the maximums observed during sintering to initial bond improvement and subsequent formation of brittle intermetallic compounds. Metallographic examination of the diffusion zone verified the formation of up to four intermediate phases.

Studies of aluminum-aluminum compacts rolled to a reduction of 65% immediately after cleaning indicated that the thin oxide layer formed at the interface tended to agglomerate and then to disappear with increasing sintering time. The authors conclude that this oxide decrease results from a gradual absorption into the bulk metal of the compact.

Microhardness profiles were made across the sintered bond interface

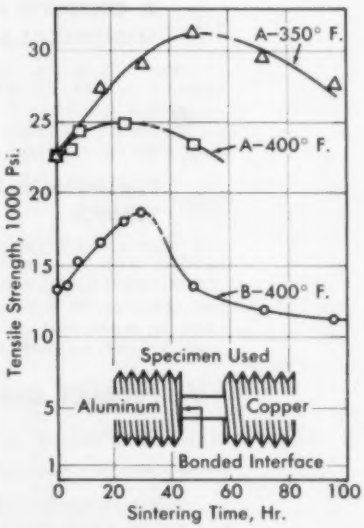

Fig. 1 – Tensile Strength of Aluminum-Copper Composites as a Function of Sintering Time. "A" and "B" designate different surface conditions

LAWN•BOY reports cost of finishing parts cut appreciably with *Hammond* Abrasive Belt Grinders

LAWN•BOY LAMAR, MISSOURI
DIVISION OF OUTBOARD MARINE CORPORATION
OVERLAND 2-4665

July 22, 1959

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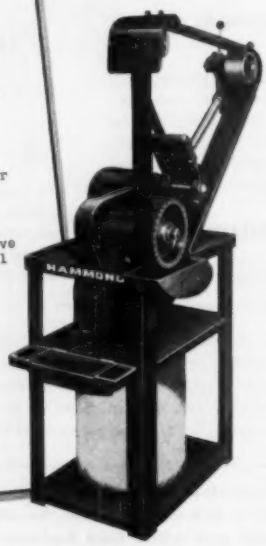
Fred Bohmsieft — Tool Designer

This letter from Lawn-Boy is typical . . . users report that Hammond Abrasive Belt Grinders reduce many costly hand filing, grinding, polishing, deburring and chamfering operations.



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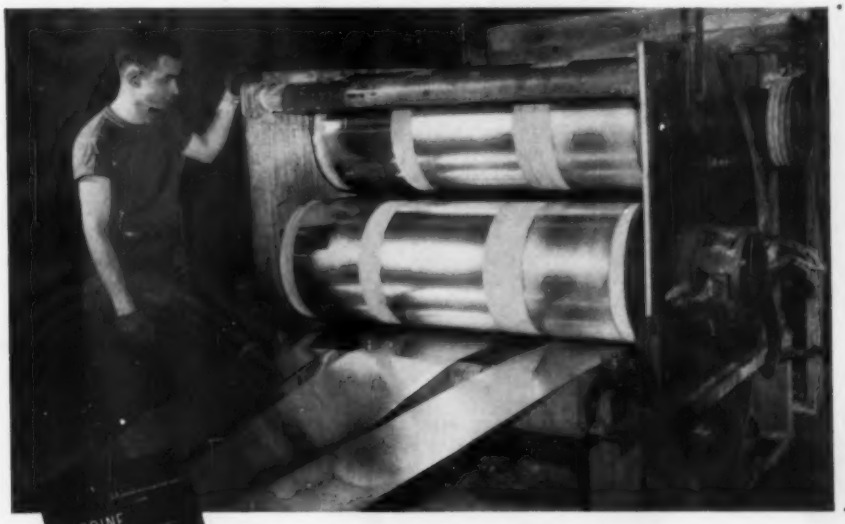
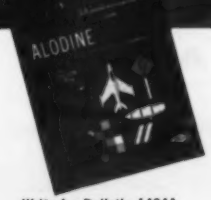


Typical ALODINE 1200S strip line installation at ALSCO, INC. Strip from aluminum coil is fed into Alodine processing baths where it is cleaned, rinsed, deoxidized, rinsed, coated with ALODINE 1200S, rinsed and given a final acidulated rinse. Strip is then rewound, roll coat painted, roller formed into final shape, backed, inspected and packed for final shipment.



Write for Bulletin 1424A describing use of Alodine for aluminum fabrications of all types.

AMCHEM

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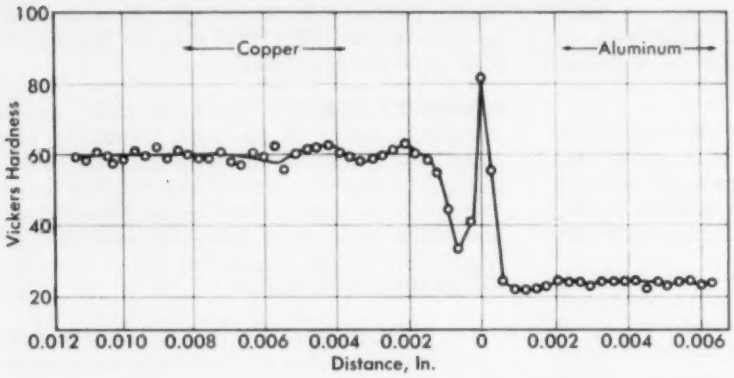
Al-Cu Composites . . .

using a Bergsman tester. Extremely careful control was necessary to obtain reproducible results. Several transverses were made of each specimen at an angle of 20° to the interface. A typical profile is shown in Fig. 2. The authors suggest that the hardness peak near the interface is associated with the formation of intermediate phases and that the dips in the hardness curve adjacent to the interface are associated with possible pore formation resulting from the Kirkendall effect.

Examinations were made of all fracture surfaces. The appearance of these surfaces permitted some qualitative conclusions concerning behavior of brittle oxide films during rolling and subsequent effect upon properties. W. R. UPTHEGROVE.

Fig. 2 – Microhardness Profile Through Al-Cu Interface. Material was sintered 24 hr. at 400° F.



Textures in Extruded Uranium

Digest of "Textures in Extruded Uranium", by R. B. Russell, ● Preprint No. 124, 1959.

THE TEXTURES in extruded uranium have been studied by the pole density method of Harris-Mueller and Knott. Thermal expansion data are used to support the X-ray evidence of the preferred orientations. Results have been obtained on as-extruded, cold swaged, recrystallized, and beta quenched uranium, and an attempt is made to predict the thermal expansion from a knowledge of texture and the three principal crystallographic thermal expansion coefficients.

Crystallographic pole figures are shown for all samples in both the extrusion and transverse directions. The hot extruded bar showed the most intense texture with the (110) poles parallel to the extrusion direc-

(*Continued on p.* 232)

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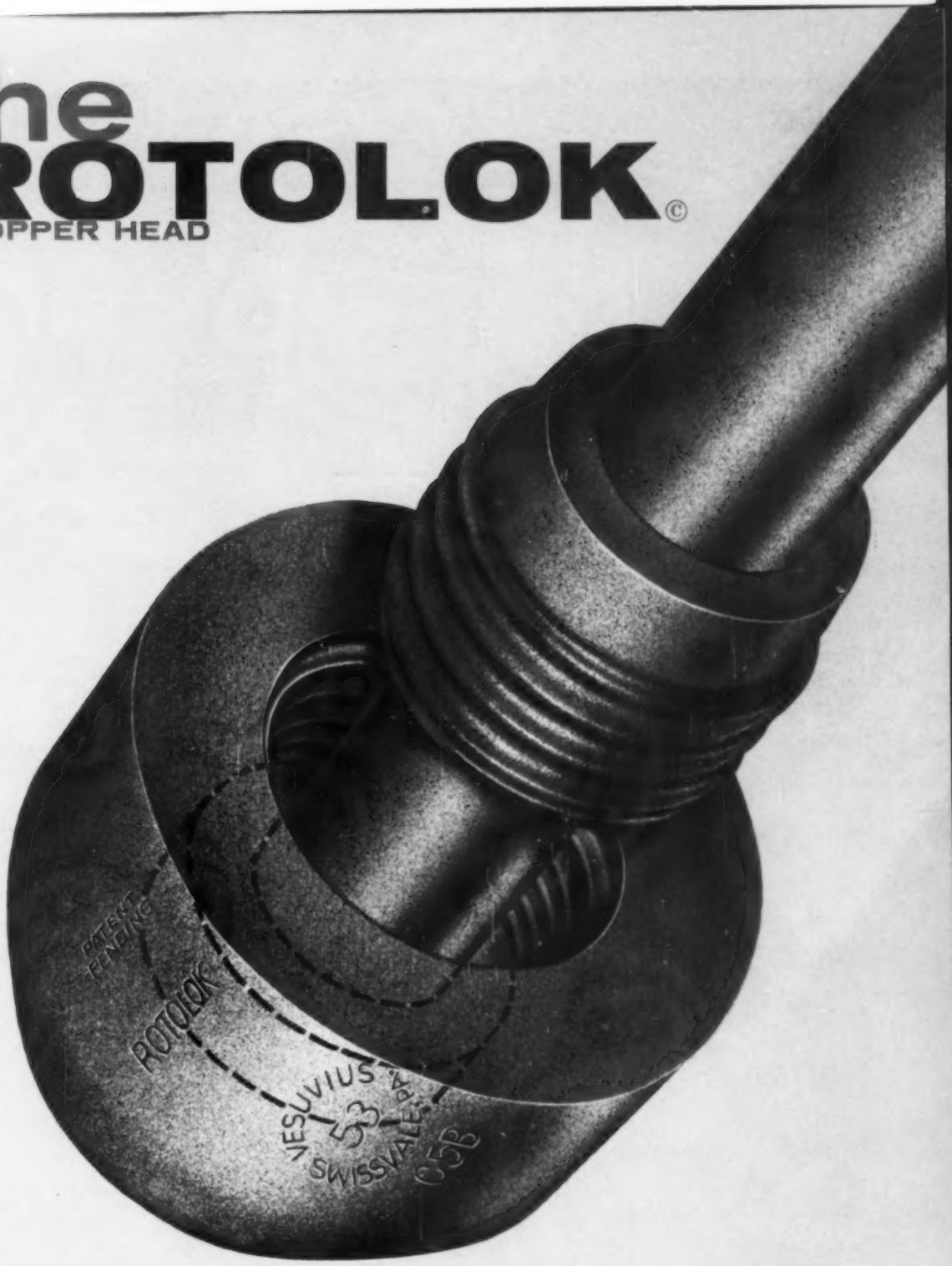

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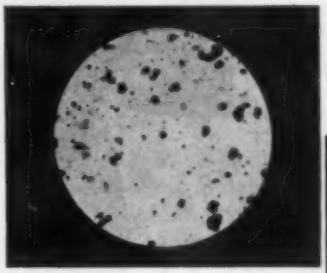
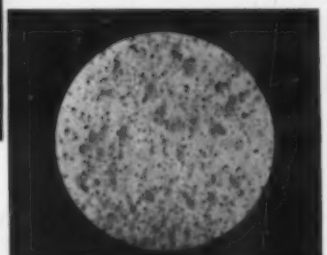
The same advantages of molybdenum disulfide can be incorporated in petroleum oils and polyalkylene glycol fluids. 'dag' Dispersions 200 and 207 are the finest colloidal concentrates available for these applications. Experimental samples may be obtained upon request.



Shown here is a dramatic comparison of particle sizes. Both Acheson's new dispersion, 'dag' 208, (below) and the finest commercially available molybdenum disulfide powder (at left), have been magnified 300 times.



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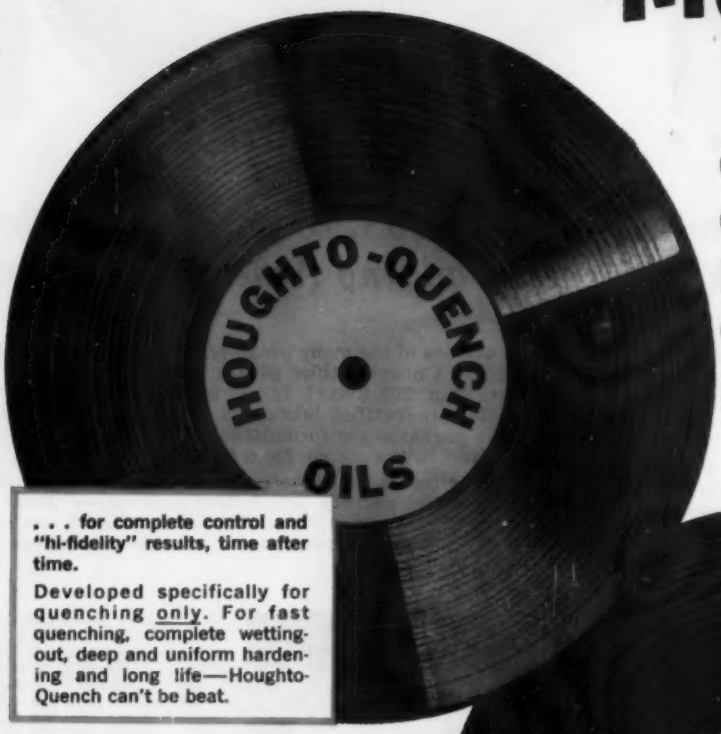

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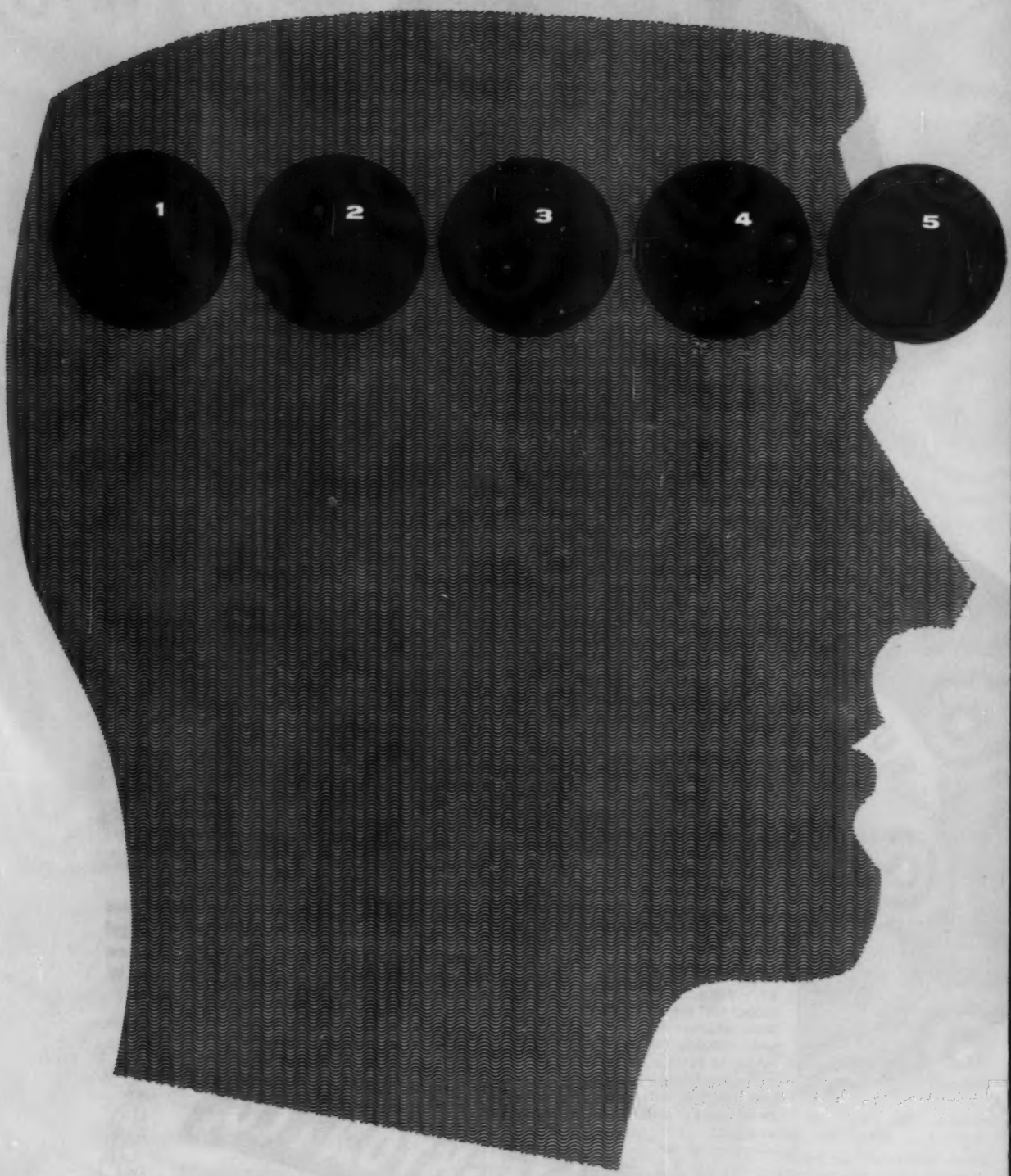
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count to ten . . .

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tion and the (001) poles parallel to the transverse direction. When a bar with this texture was cold swaged, the texture degenerated to one with the (010), (150), (130) and (120) poles parallel to the original extrusion direction, but with the density of the (110) poles markedly reduced. The orientation of the (001) poles was much more stable to cold working.

After recrystallization, the texture in the extrusion direction of the cold swaged rod shifted towards the (130) pole and was somewhat more degenerate than before recrystallization. As before, the orientation of the (001) poles was stable.

The (110) hot extruded texture was completely destroyed by beta treatment and the grain orientations were nearly random.

The results obtained are in agreement with predictions made by Calnan and Clews and with the experimental results of Mitchell and Rowland. The results are discussed in terms of the relative amounts of twinning and slip that occur during the deformation process.

From the textures observed, the linear thermal expansion was calculated and compared to measured values. Differences between the two values were found, but the difference was only 2% in the case of the as-extruded metal, which is of course the least disturbed texture.

W. C. WINEGARD

Cobalt-Tungsten Carbide Alloys

Digest of "Experimental Survey of the Deformation of the Hard-Ductile Two-Phase Alloy System WC-Co", by C. Nishimatsu and J. Gurland, ⊜ Preprint No. 155, 1959.

THIS PAPER is a study of the strength and deformation behavior at room temperature of alloys of cobalt and tungsten carbide over the entire range of the two-phase system. All alloys were prepared and mechanically tested by standard powder metallurgy techniques. Representative photomicrographs showing the nature of deformation and fracture for various compositions are presented in the paper.

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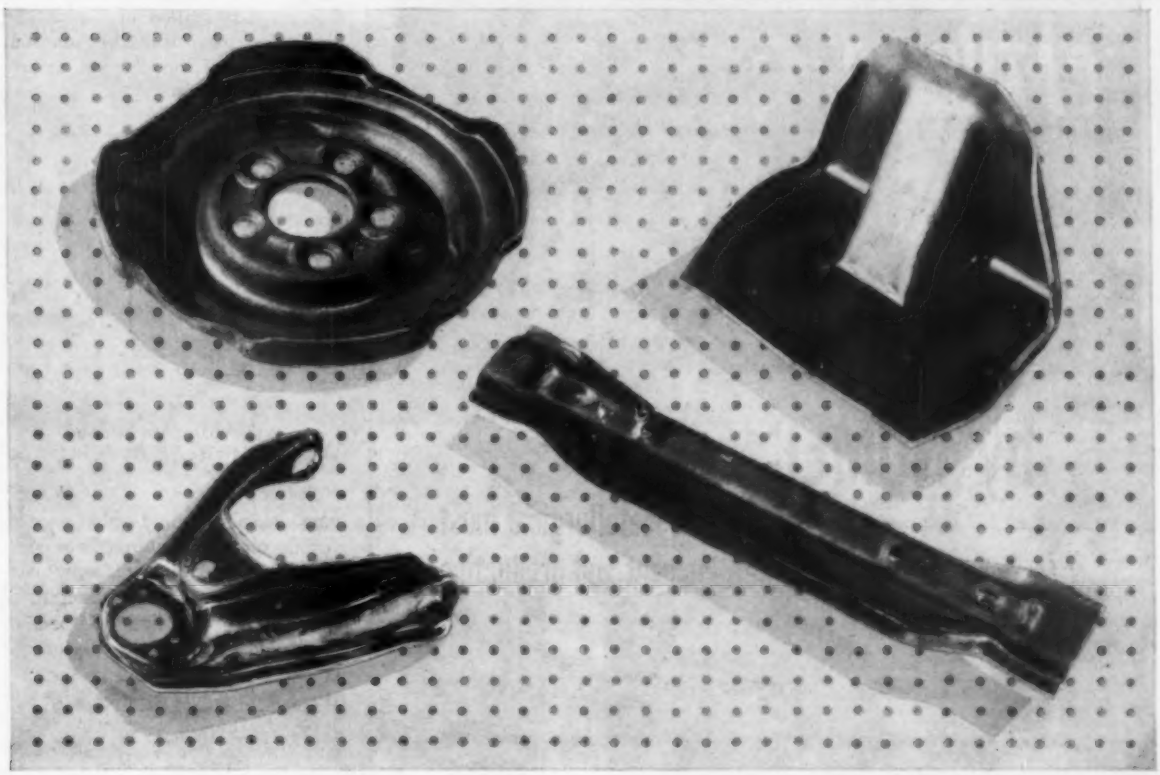

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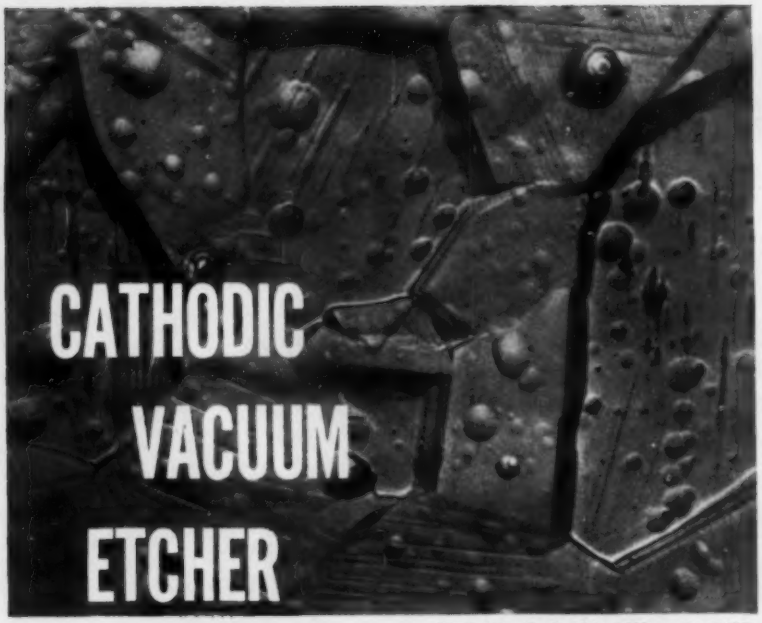

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Co-WC Alloys . . .

The accompanying figure (Fig. 1) shows the effects of the volume per cent of the ductile cobalt matrix phase on the fracture strength of various alloys in tension and bending. Near the cobalt end of the composition diagram, alloys fail through deformation of the ductile cobalt martrix; near the tungsten carbide end of the diagram, failure

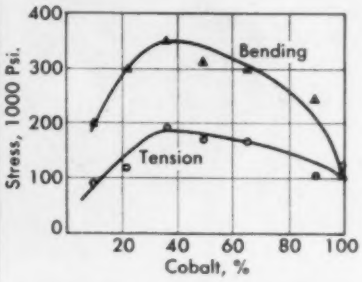

Fig. 1 – Fracture Strength in Tension Bending

is by cleavage of the brittle tungsten carbide phase. In intermediate compositions, failure takes place by plastic flow of the matrix and fracture of the carbide particles. Dispersion hardening of the matrix by carbide particles causes restraint of the matrix, permitting high stresses to be carried by the carbide phase. The embrittlement of the alloys with large amounts of carbide is due both to the presence of a brittle phase and to the restraint of plastic deformation of the ductile phase in contact with the rigid carbide particles.

P. D. Frost

Decomposition of Metastable Phases

Digest of "Kinetics of Decomposition of Alpha Prime in a Titanium-Copper Alloy", by M. P. Gomez and D. H. Polonis, Preprint No. 147, 1959.

This research was designed to develop fundamental information on the kinetics of decomposition of metastable phases in alloy systems – particularly nonferrous systems. (Previous fundamental work had been confined largely to iron-carbon alloys.) The investigators specifi-

Which picture do you fit?

Here are four *actual* customers* with different, but exacting product and technical needs. One uses Bridgeport rod in a range of alloys, the second Bridgeport strip. A third makes fasteners from Bridgeport Brass wire. The fourth company uses Bridgeport condenser tubes *and* Technical Service to produce quality heat exchangers. Which picture do you fit with your raw materials and manufacturing requirements?

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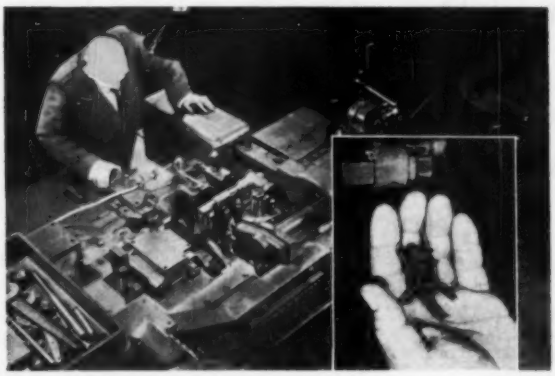
"LONG-LENGTH COILS. They're one reason why we can depend on Bridgeport for strip," says Customer B. "Superior surface finish from Bridgeport saves us production costs. With their Sendzimir mill finish and exact gauge and width in long-length coil, you can see the reasons why we depend on Bridgeport for brass, copper and aluminum strip."



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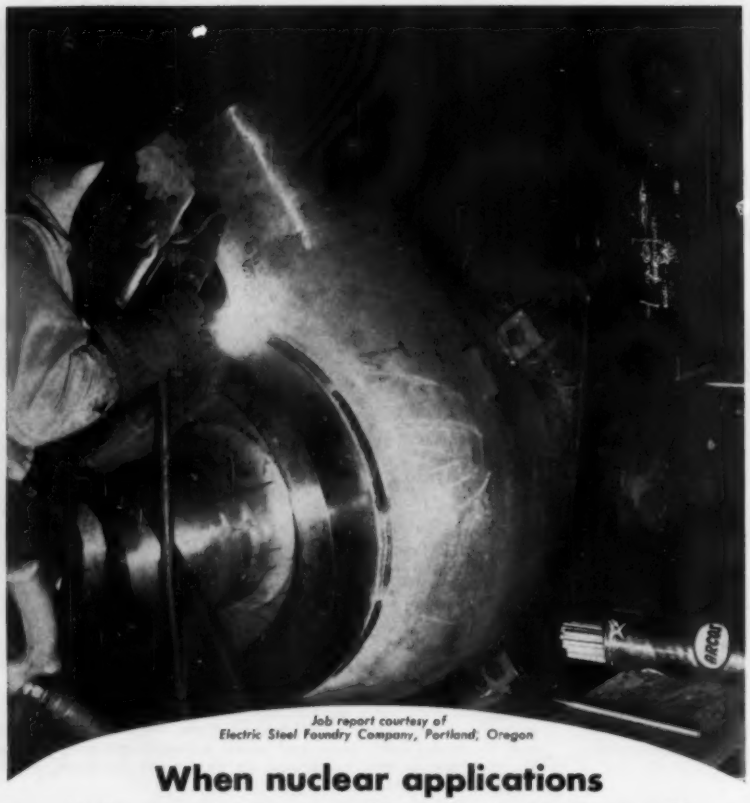

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Metastable Phases . . .

cally attempted to correlate measured activation energies, crystallographic processes and microstructures as related to the decomposition kinetics of transformed beta (alpha prime) in a titanium-copper alloy.

In the present investigation, quenched and tempered specimens were examined by microscopic, X-ray diffraction, microhardness and electrical resistivity methods. Hardness and microstructural studies indicated two different but competing reactions during the tempering of alpha prime. One involved relatively rapid decomposition of alpha prime at former beta grain boundaries, while the other concerned precipitation within the prior beta grains, with characteristics similar to a precipitation hardening reaction. Electrical resistivity values were used to calculate the fractional decomposition of alpha prime for each tempering time and temperature. Several reaction equations were applied to these data to determine the types of kinetic behavior descriptive of the decomposition reaction. From these data, the authors have concluded that the tempering of the alpha prime phase has characteristics, up to 60% transformation, of a log autocatalytic reaction such as has been used to describe decomposition of austenite in steels as well as some precipitation hardening reactions. Beyond 60% (and especially at higher temperatures), a Cohen-type equation, similar to that applied to the first stage of tempering in steels could be used.

The authors have suggested a mechanism for the tempering reaction which takes into account these equations and the following observed facts:

1. Variation in resistivity resulting from variation in state of strain in the matrix, variation in number and relative amounts of phases involved in the transformation, and depletion of solute in the alpha prime.

2. Formation of most of the visible precipitate at former grain boundaries.

3. Continuous increase in hardness inside former beta grains, for some temperatures.

4. Visible breakdown of martensite plates.

5. Initially high reaction rate and a low growth coefficient value.

6. Slight increase in reaction rate after transformation of the first 60%.

The suggested tempering reaction mechanism include the following: Two processes occur at the beginning of tempering. Precipitation involving an age hardening-type reaction starts inside the prior beta grains, and precipitation at a much faster rate occurs at the former beta boundaries. The reaction within the beta grains involves coherent growth of the nuclei which are readily formed in the potentially numerous and highly strained interfacial regions between alpha prime platelets. This reaction is probably growth controlled, with the growth stage involving the formation of a coherent precipitate. Precipitation at the former beta grain boundaries proceeds by direct particle growth without depending on nucleation, and apparently has a greater effect on the reaction in its initial stages. Coherent growth within the alpha prime grains becomes an important factor in the reaction only in its later stages. E. C. MILLER

Oxygen Diffusion in Titanium

Digest of "Diffusion of Oxygen in Alpha and Beta Titanium", by P. Roe, H. R. Palmer and W. R. Opie, Preprint No. 159, 1959.

DIFFUSIVITIES of oxygen in alpha and beta titanium were determined using microhardness data as measures of oxygen content. The samples used were ¼-in. diameter cylinders, 1 in. long, of commercially pure titanium analyzing 0.09% O, less than 0.1% N, and 0.01% H. These were abraded, degreased, and packed tightly in TiO_2 powder within a quartz combustion crucible.

The crucible was heated in a nickel bomb containing an argon atmosphere. Diffusion was measured by cutting and polishing a transverse section of the specimens midway along the long axes. These sections were examined metallographically and microhardness measurements made adjacent to the surface of the bar and at a known distance from the surface.

Specimens to determine diffusivity

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Oxygen Diffusion . . .

in beta titanium were oxidized between 1700 and 2070° F. for 6 to 27 hr. These specimens had a case of untransformed alpha and a core of transformed alpha. Microhardness measurements were made along an area of the transformed alpha, which had been beta at the diffusion temperature.

The results are plotted in the accompanying figure, and from these data the following equation was developed for diffusivity of oxygen in beta titanium:

$$D_\beta = 3.14 \times 10^4 e^{-68{,}700/RT} \text{ sq. cm. per sec}$$

These diffusivity data were compared with measurements of the rate of diffusion of oxygen outward from small cubes of titanium containing originally 0.43% O. These cubes were held at 1830 to 2100° F. in a

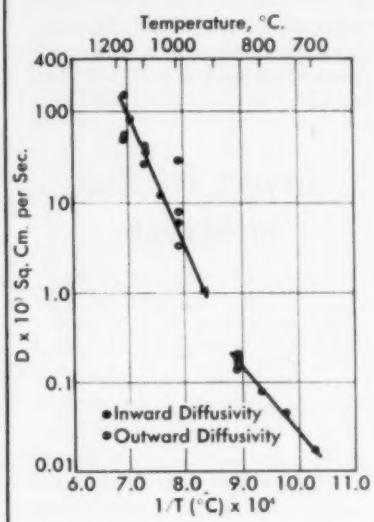

Fig. 1 — Diffusivity of Oxygen in Alpha and Beta Titanium

bath of calcium sealed in an argon-filled nickel bomb, the purpose of the calcium being to absorb the oxygen as it diffused out of the cubes. The white points in the figure show the outward diffusion rate data. Similar deoxidation experiments were conducted on small samples of unalloyed titanium sheet. Fairly close predictions were made of the amount of oxygen that would be removed by the calcium treatment, based on the diffusivity data.

The diffusivity of oxygen in alpha

titanium was determined by the same technique used for beta titanium, except, of course, lower temperatures and longer times were used. The results are also plotted in the accompanying figure and the equation developed was as follows: $D\alpha = 5.08 \times 10^{-3} e^{-33,500/RT}$ sq. cm. per sec.

The authors point out that the data developed in this work are only semiquantitative because no concentration gradients were actually determined and the effects of impurities, grain boundaries, and grain orientation were not considered. However, the diffusivity data were in fair agreement with the results of the actual deoxidation experiments.

P. D. FROST

Aging and Notch Fatigue in Aluminum

Digest of "A Study of the Relationship Between State of Aging and Notch-Fatigue Performance of a High-Strength Aluminum Alloy", by G. W. Form, ⊖ Preprint No. 126, 1959.

THIS PAPER presents the results of an investigation aimed at establishing the relationship between fatigue performance of notched specimens and state of aging in a duralumin-type alloy (2014 alloy). The tests were performed on an axial-load fatigue machine under a stress of 28,500 psi. at room temperature and at −110° F.

It is well established that the high-strength aluminum alloys owe their excellent static strength properties to controlled precipitation from a supersaturated solid solution. Unfortunately, these high static strengths are not of much benefit in structures subjected primarily to cyclic stresses because the ratio of fatigue to static strength of these alloys is comparatively low. A number of researchers have studied this problem in the last few years, and all have decided that the poor response of high-strength aluminum alloys is due to overaging promoted by cyclic stresses. Although there is evidence that lends support to the "overaging theory", it is by no means conclusive. The concept of the "overaging theory" is based on the thermodynamic instability of high-strength aluminum alloys, and im-

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Aluminum . . .

plies that precipitation is accelerated by the action of alternating stresses. However, there is ample evidence to show that plastic deformation may accelerate or decelerate the aging process. Which tendency predominates depends on the thermodynamic and mechanical stabilities of the alloy. These, in turn, depend upon the time and temperature at which prior aging was performed and on the temperature of cold working.

Extruded 2014 alloy was a judicious choice of material for this investigation because it requires artificial aging to reach maximum hardness, and furthermore, it can be readily stabilized against precipitation at ambient temperature. This is clearly shown by Fig. 1.

In spite of this apparent thermodynamic stability, the results of notch fatigue tests both at room temperature and at −110° F. (obtained under a stress of 28,500 psi.) show that the fully hardened material performs much more poorly in notch fatigue tests than the soft material. This, despite the higher ratio of static yield to applied cyclic stress in the case of the fully hardened state. These results of room temperature tests are summarized in Table I.

Table I — Room Temperature Tests

Aging Time at 340° F.	Yield Strength	Yield Strength: Applied Stress	Average Life
½ hr.	45,000 psi.	1.59	97,370 cycles
1	52,000	1.83	99,640
2	63,000	2.22	40,670
7	75,000	2.64	39,690
48	64,000	2.24	37,110

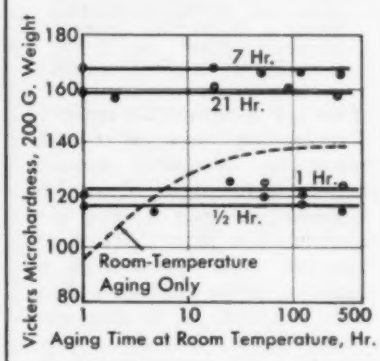

Fig. 1 — Effect of Room Temperature Aging on Hardness of Samples Previously Aged at 340° F.

Figure 2 shows a similar trend in impact energy as a function of aging time.

Metallographic examination of specimens from interrupted fatigue tests led the author to the conclusion that the superior fatigue performance of lightly aged specimens is a result of a higher resistance to both crack formation and crack propagation. Microhardness measurement of fully hardened material revealed that very soft regions are present

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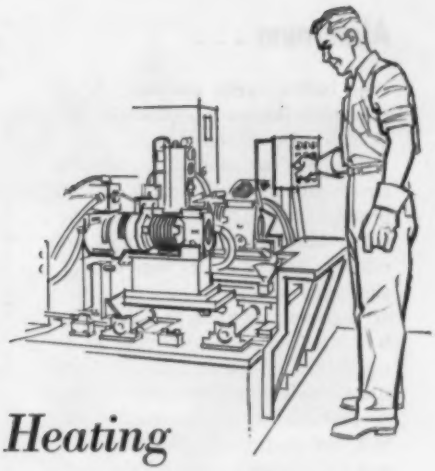

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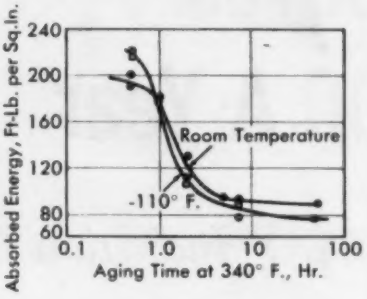
Aluminum . . .

even before cyclic stressing; deviations from the mean hardness as high as 50% were recorded.

The author concluded that the structural inhomogeneity is the important factor in the lack of correlation between static strength and fatigue behavior of high-strength aluminum alloys. High static yield or tensile strength of the bulk alloy is of little significance in cyclic stressing if the structure contains weak spots which have a resistance to plastic deformation of the order of one half that typical of the bulk material, and if the latter is embrittled to such an extent that its capacity for plastic deformation in the presence of a stress-raiser is seriously impaired.

Fig. 2 – Impact Energy as a Function of Aging Time at 340° F.



It should be possible to reduce the adverse effect of these soft or weak areas, and thus improve the fatigue performance of fully hardened specimens through suitable mechanical and thermal processing or close control of the chemical composition, or both.

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A demonstration of the new MARVEL No. 81 All Hydraulic Band Saw will prove it. Write today for the complete story, and ask about a demonstration.

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MARVEL Metal Cutting SAWS
Better Machines–Better Blades

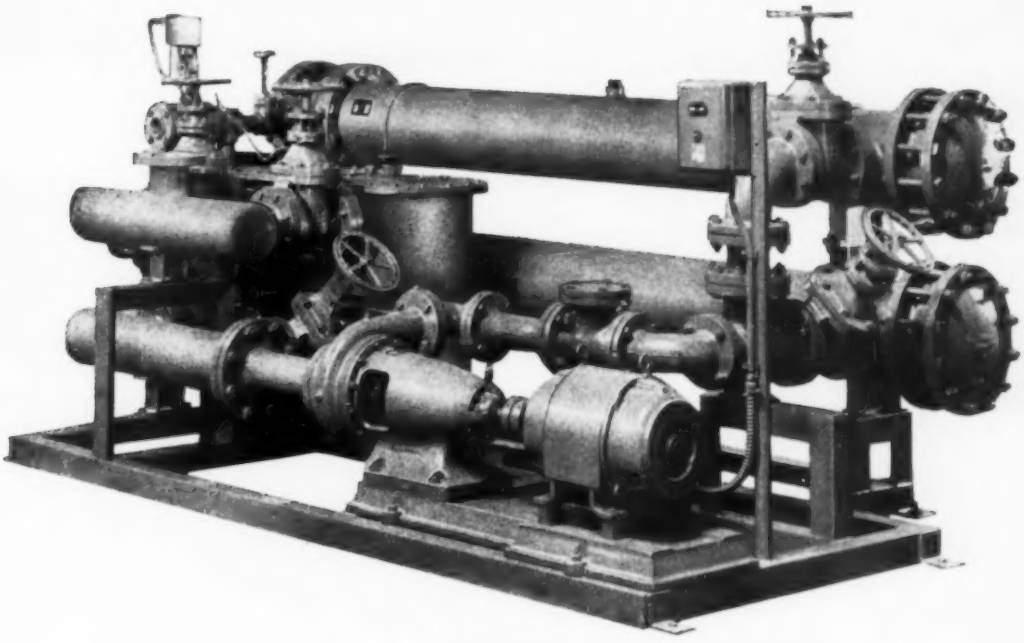
Columbium-Oxygen System

Digest of "Columbium-Oxygen System", by Rodney P. Elliot, Preprint No. 143, 1959.

THIS PAPER makes a significant contribution to the metallurgy of high-temperature materials by providing those interested in columbium with a well-authenticated equilibrium phase diagram of the columbium-oxygen system. In investigations of phase equilibria, the purity of the starting materials is of utmost importance; in the case of columbium, the problem of purity is of particular concern because of its ability to "getter" oxygen. For this investigation, the author used a special-grade columbium, refined by an electron bombardment melting technique which eliminates virtually all oxygen, nitrogen, hydrogen and carbon when present in amounts less than oxygen, as well as metallic impurities of low vapor pressure. The effectiveness of this refining process in removing interstitials is evidenced by a comparison of hardness: arc-melted columbium has a Vickers hardness of 141 compared with 55 after refining. The alloys were made by arc melting the pure columbium with high-grade Cb_2O_5 especially processed to minimize metallic impurities.

The phase boundaries were determined by metallographic structure analysis, and excellent photomicrographs of the various structures are presented. The salient features of the diagram are as follows: (*a*) the three oxides of columbium, CbO, CbO_2 and Cb_2O_5, have negligible solid solubility and melt congruently at 1945°, 1915°, and 1495° C. (3530, 3480, 2725° F.); (*b*) a eutectic reaction occurs at 1915° C. (3480° F.): Liquid $_{19.5\%\ O} \rightarrow Cb_{0.73\%\ O} + CbO$ and another at 1810° C. (3300° F.): Liquid $_{21\%\ O} \rightarrow CbO + CbO_2$;

(*Continued on p. 248*)



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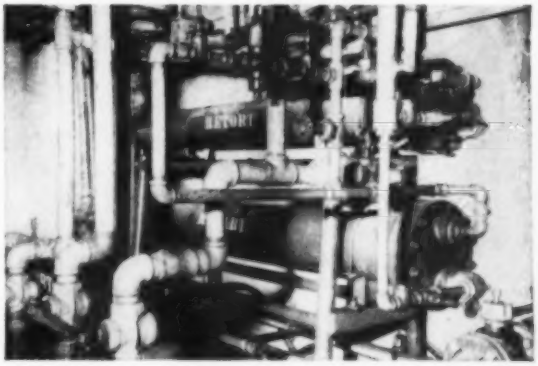

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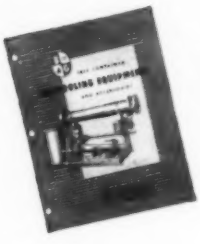

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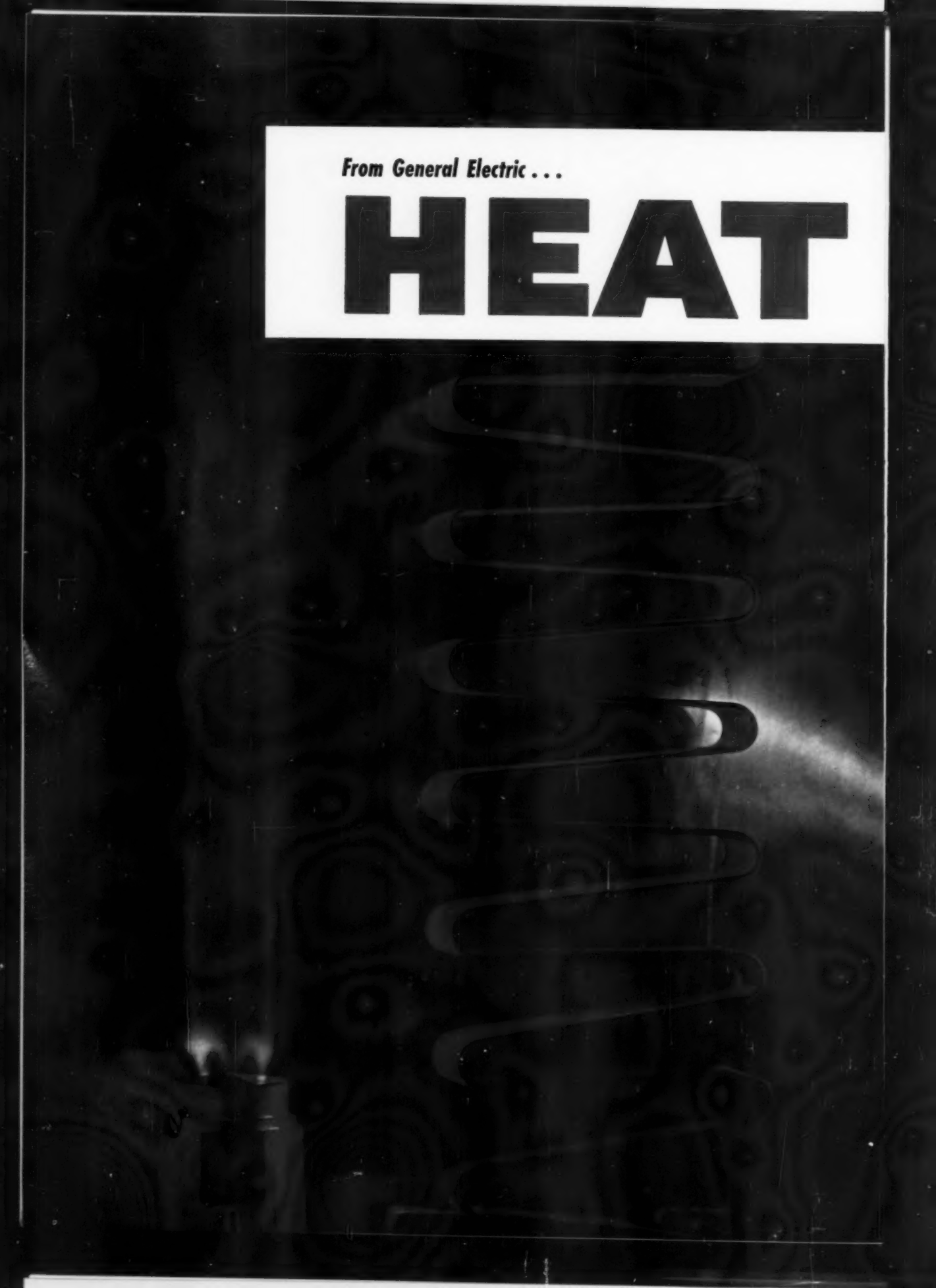

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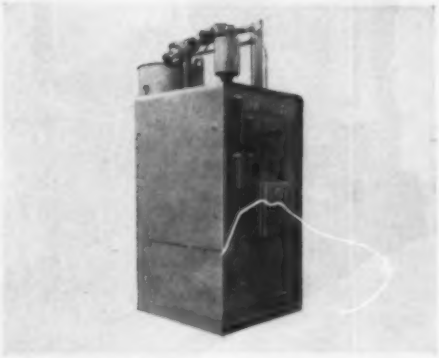

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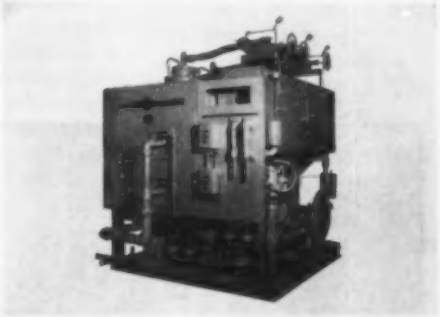

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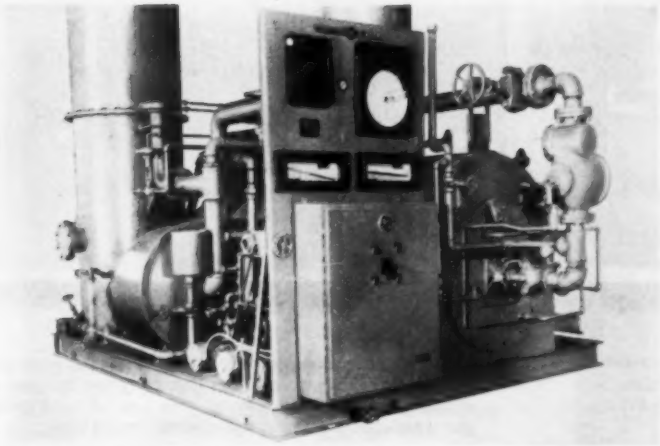

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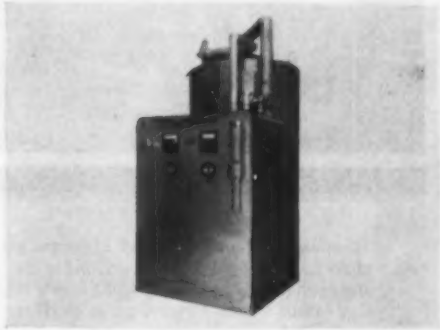

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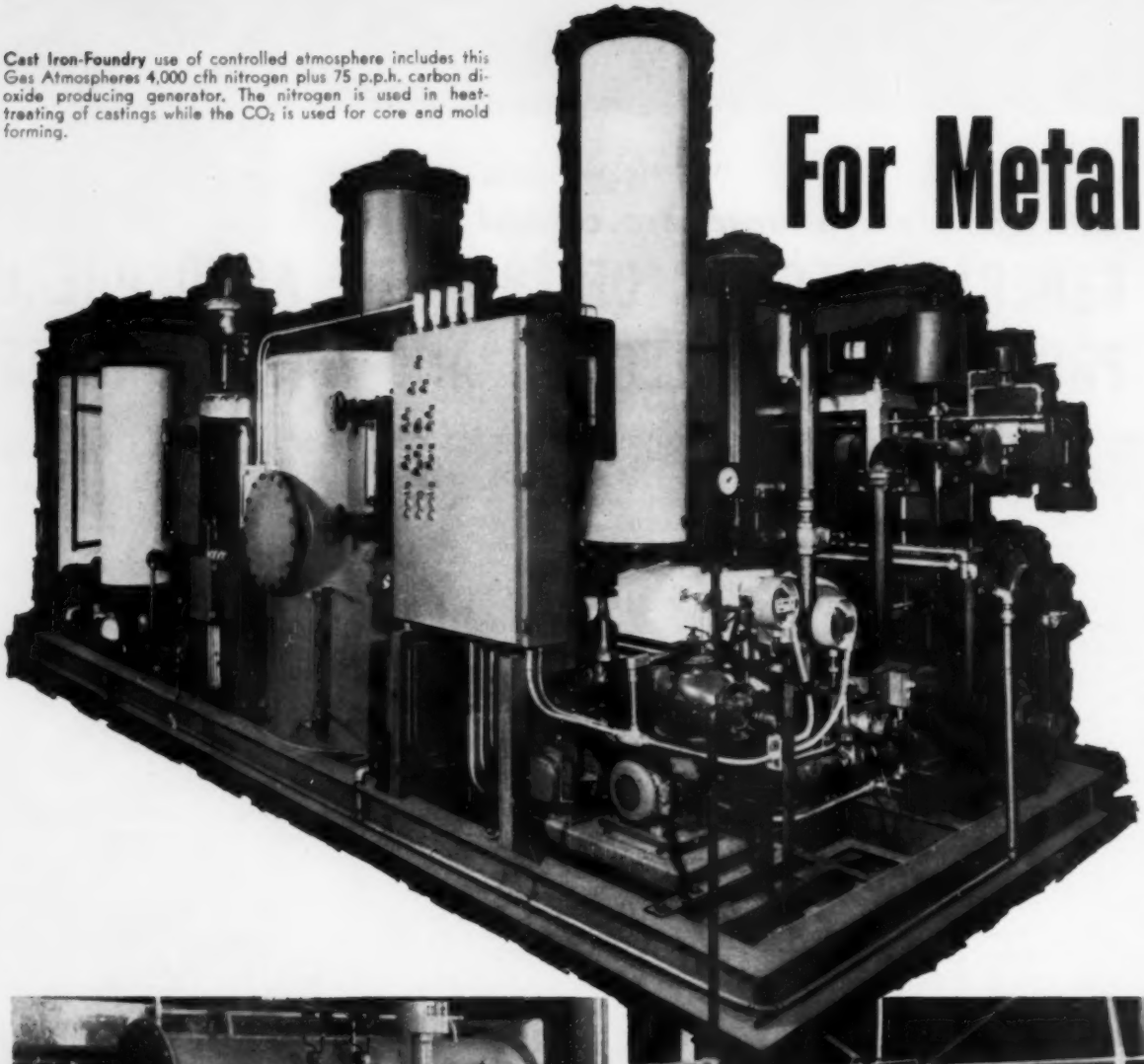

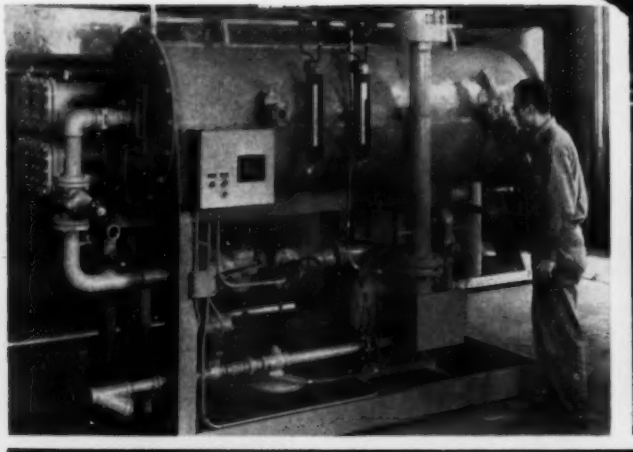

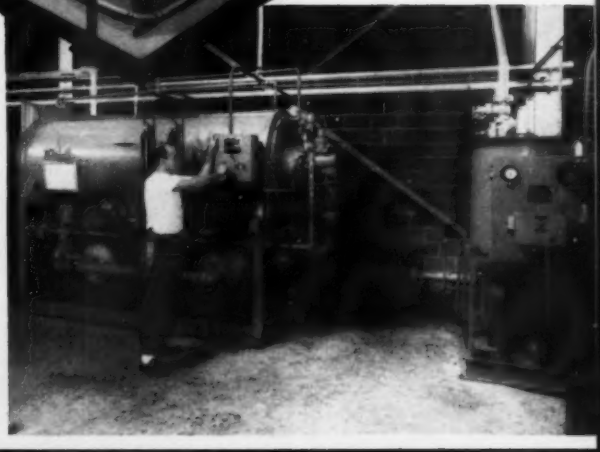

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Brass, Copper and Aluminum mill products produced by the Scovill Manufacturing Company are brought to exacting specification through the use of exothermic gas produced in Gas Atmospheres generators.

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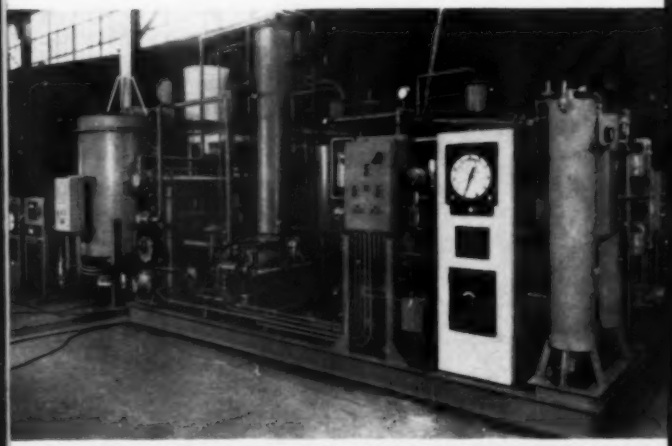

You get unsurpassed experience, too, when you call Gas Atmospheres

Partial List of Gas Atmospheres Metal Producing and Fabricating Customers

Acme Steel Company
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Alan Wood Steel Co.
American Brass Company
American Screw Company
American Smelting and Refining Company
American Steel & Wire
Armco Steel Corporation
Bethlehem Steel Company
Bridgeport Brass Company
Chase Brass & Copper Co., Inc.
Colorado Fuel & Iron
Continental Steel Corp.
Copperweld Steel Co.
Detroit Steel Co.
Douglas Aircraft Co., Inc.
Goodyear Aircraft Corp.
Granite City Steel Co.
Holo-Krome Screw Co.
Hughes Aircraft Co.
International Nickel Co., Inc.
Johnson Bronze Co.
Jones & Laughlin Steel Corp.
Kaiser Steel Corporation
Keystone Steel & Wire Company
Lamson & Sessions Co.
Lycoming Div. of AVCO Corp.
Mallory-Sharon Metals
Martin Aircraft
McLouth Steel Corp.
North American Aviation, Inc.
Phelps Dodge Refining Corp.
Piasecki Helicopter Corp.
Pratt & Whitney Aircraft Div.
Republic Steel Corp.
Revere Copper & Brass, Inc.
Reynolds Metals Co.
Roebling, John A., Sons Co.
Rome Strip Steel
Russell Burdsall & Ward Bolt & Nut Co.
Scovill Manufacturing Co.
Sheffield Div. of Armco Corp.
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Columbium-Oxygen . . .

(*c*) a peritectic reaction at 1510° C. (2750° F.), Liquid $-_{29.5\%\ O}+ CbO_2 \rightarrow Cb_2O_5$, is proposed, but the experimental evidence is inconclusive and this portion of the diagram needs further study. The solid solubility of oxygen in columbium is 0.25 at 500° C. and increases to 0.72 at the eutectic temperature (1915° C.)

X-ray studies confirmed the crystal structure of CbO as simple cubic, with a lattice parameter of 4.210 A. No allotropy was detected in Cb_2O_5.

H. H. CHISWIK

Fractures in Forgings

Digest of "The Influence of Pre-Existing Sharp Cracks on Brittle Fracture of a Ni-Mo-V Forging Steel", by E. T. Wessel, Preprint No. 173, 1959.

THE EFFECT of a cleavage crack on the transition from brittle-ductile behavior was examined in specimens of a typical rotor steel. In cylindrical specimens, both notch and unnotched, brittle cleavage fracture does not occur at the low stresses and moderate temperatures encountered in service. If, however, one forms a cleavage crack in a specimen, this crack will propagate in a brittle manner if the specimen is then stressed at much lower average stresses and higher temperature than for ordinary notched specimens. For the particular 3% Ni, 0.50% Mo, 0.1% V steel which has a 50% ductile transition temperature of −60° F. unnotched and +200° F. notched, brittle failure occurs at +250° F. for cracked specimens. Concurrently, the stress required to initiate fracture drops to less than 67% of that of the normal yield strength. The rapid decrease in the strength in the crack notch test occurs in the same temperature range as the decrease in energy absorption in a Charpy V-notch test. Similar comparisons can be made on the basis of fracture appearance.

The values of critical crack extrusion force G_c can be calculated for the crack notch test and are found to be somewhat lower than for notched rotating disks. This difference is probably related to the

METALGRAMS

. . . news about metals and metal chemicals

UNION CARBIDE METALS

Electromet brand ferroalloys, pure metals and metal chemicals

Purity previously unattained commercially is now available in Union Carbide Metals' high-purity chromium. This product was introduced in 1958 in response to the requirements of nuclear energy development and high-temperature alloy research. Union Carbide Metals can now offer high-purity chromium having a total impurity level as low as 300 ppm. The newest of the 44 grades of "Electromet" chromium is available in semi-commercial quantities at considerably less than the price of iodide chromium. Write for Data Sheet CR1-MP-3.

* * *

Acetylacetonate derivatives of the transition metals (for example, chromium, cobalt, manganese, vanadium, iron, and nickel) have recently been made available in research quantities by Union Carbide Metals. These "Electromet" acetylacetonate compounds provide a convenient means of putting the metals in solution in organic systems; the compounds are chelated, non-ionizing substances, slightly soluble in water. They form solutions which are neutral and resistant to hydrolysis. The acetylacetonates are available in the form of pure, crystalline powders of medium bulk density. Bulletin AA1-MP-3 gives details.

* * *

Time-saving mixes, having proved their worth in the kitchen, have now moved into the metallurgical field. Examples of this concept are Union Carbide Metals' more than 15 titanium alloy addition agents. The first of these was 85% vanadium-aluminum, developed in 1954 to expedite commercial production of the high-strength 6 Al-4V titanium. The list now includes a tantalum-columbium-aluminum combination for the new 8-8-1 alloy. Data Sheet AT1-MP-3.

* * *

Among the Union Carbide Metals family of oxides are columbium and tantalum oxides. Both have high dielectric constants useful in electronics. Columbium oxide is also an intermediate material for producing compounds with great hardness and high melting point. Tantalum oxide is a source for tantalum carbide, a cutting tool additive which increases resistance to abrasion and oxidation. Send for Data Sheet OX1-MP-3

* * *

Substantially improved specifications for vanadium metal, particularly as regards gaseous impurities, have been announced by Union Carbide Metals Company. Through the use of improved production methods, hydrogen content has been cut by 90 per cent and nitrogen and carbon contents by 50 per cent. Analyses of 500- and 1000-pound lots show that the sum of carbon, oxygen, hydrogen, and nitrogen is in the range of 0.1 per cent. Write for Bulletin VM1-MP-3.

* * *

Stainless steel shapes of more than 95 per cent theoretical density have been made from Union Carbide Metals' new stainless steel powder. The composition of the powder is similar to Type 316 or CF-Mo alloys. Mechanical properties of the sintered shapes closely approach those of wrought shapes. Union Carbide Metals field consultants, working with metal powder fabricators, are developing the promising potential for this stainless steel powder in many uses, including gears, bushings, and other shapes exposed to aggressive corrosion environments. Data Sheet SS1-MP-3 gives additional information.

* * *

Union Carbide Metals Company, Division of Union Carbide Corporation, P. O. Box 330, Niagara Falls, N. Y. In Canada: Union Carbide Canada Limited, Toronto.

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Forging Fractures . . .

greater sharpness present in the crack notch. In specimens where the effect of a saw cut and a crack were compared, the fracture always originated at the crack. In making a comparison of these data or in applying the values to service applications, the effect of section size must also be considered. The results do indicate that pre-existing cracks can greatly reduce the strength of a simple structure and change the mode of crack propagation from ductile to brittle. R. W. GUARD

Boron in Casting Alloys

Digest of "The Role of Boron in Cast Austenitic Alloys", by R. Wayne Kraft, Jr., and R. A. Flinn, Reprint No. 133, 1959. 1959.

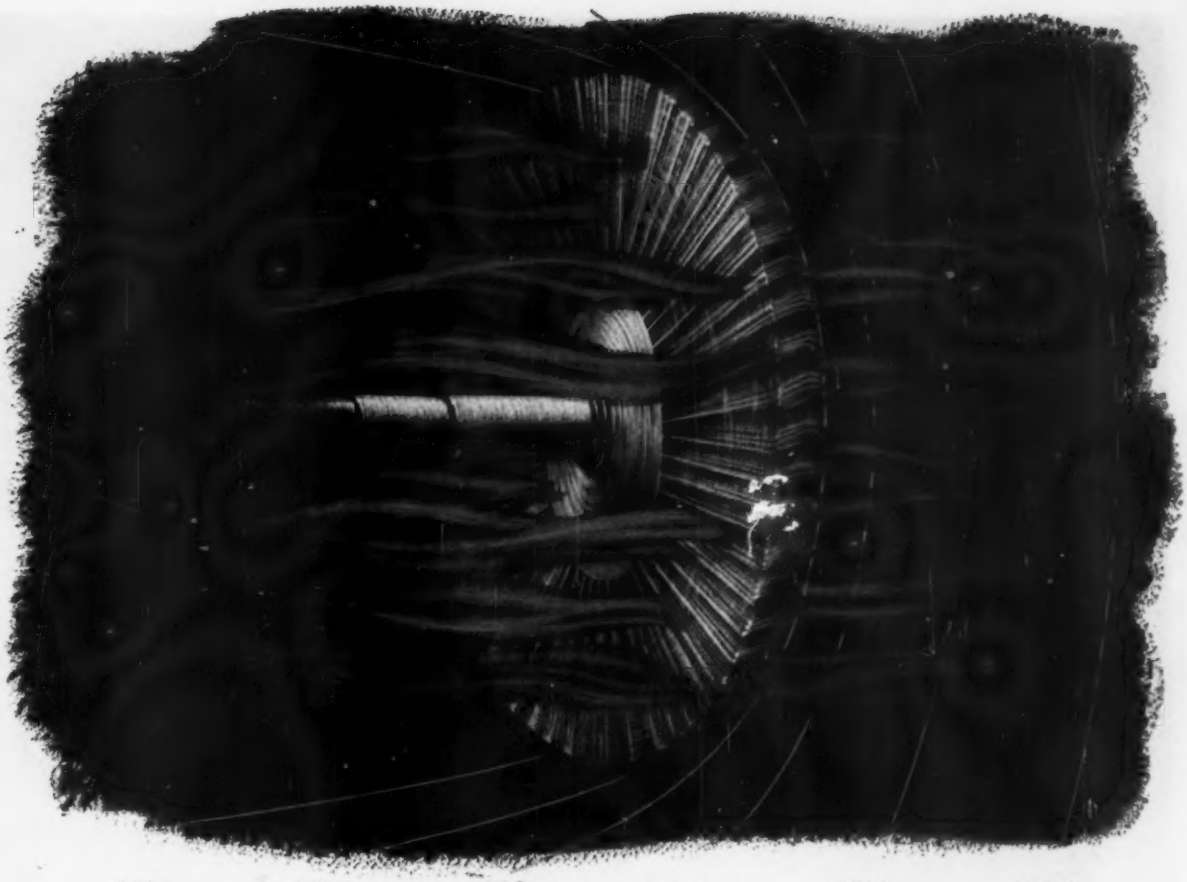
AS THE AMOUNT of boron in a cast 20% Cr, 18.5% Ni austenitic iron alloy is increased from 0.1 to 1.5%, the quantity of borides present as a grain-boundary eutectic increases. The phases present in this structure are identified as $(Fe\text{-}Cr)_2B$ and CrB by X-ray diffraction examination of extracted residues. These borides give an increase in strength at room temperature, but ductility is lowered because of cracking at the boride phase during deformation.

During rupture testing at 1500° F., the fracture proceeds by the growth of microcracks in the matrix itself. Consequently, the effect of borides is to increase the strength with little decrease in ductility. A very fine boride precipitate occurs during rupture testing; it is probably responsible for some of the increase in creep resistance. The precipitation process occurs only in stressed specimens and its effect is further enhanced by an anneal at 2200° F. prior to testing. Pretreatment reduces the tendency to microcracking.

The effect of boron in the quantities studied is different than the effect observed by Decker, Rowe and Freeman (NACA TN4049) for much smaller amounts. In the latter instance, borides themselves had little to do with the remarkable improvements in properties since the quantities present were much lower.

R. W. GUARD

(*More digests on p.* 256)



Boring into the Heat Barrier

Heat-treating facilities are part of the complete metallurgical services available at Haynes Stellite Company.

Extremely high centrifugal forces, plus prolonged operation well above 1700 deg. F.! That's the achievement of thousands of jet engine turbine wheels and blades investment-cast of HAYNES high-temperature alloys.

Resistance to stress, to thermal shock, to erosion, corrosion, and to fatigue are typical properties that make these alloys so extremely useful in many of the hot spots in today's jet engines, ramjets, missiles, and rockets.

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HAYNES STELLITE COMPANY
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Address inquiries to Haynes Stellite Company, 420 Lexington Avenue, New York 17, N. Y.

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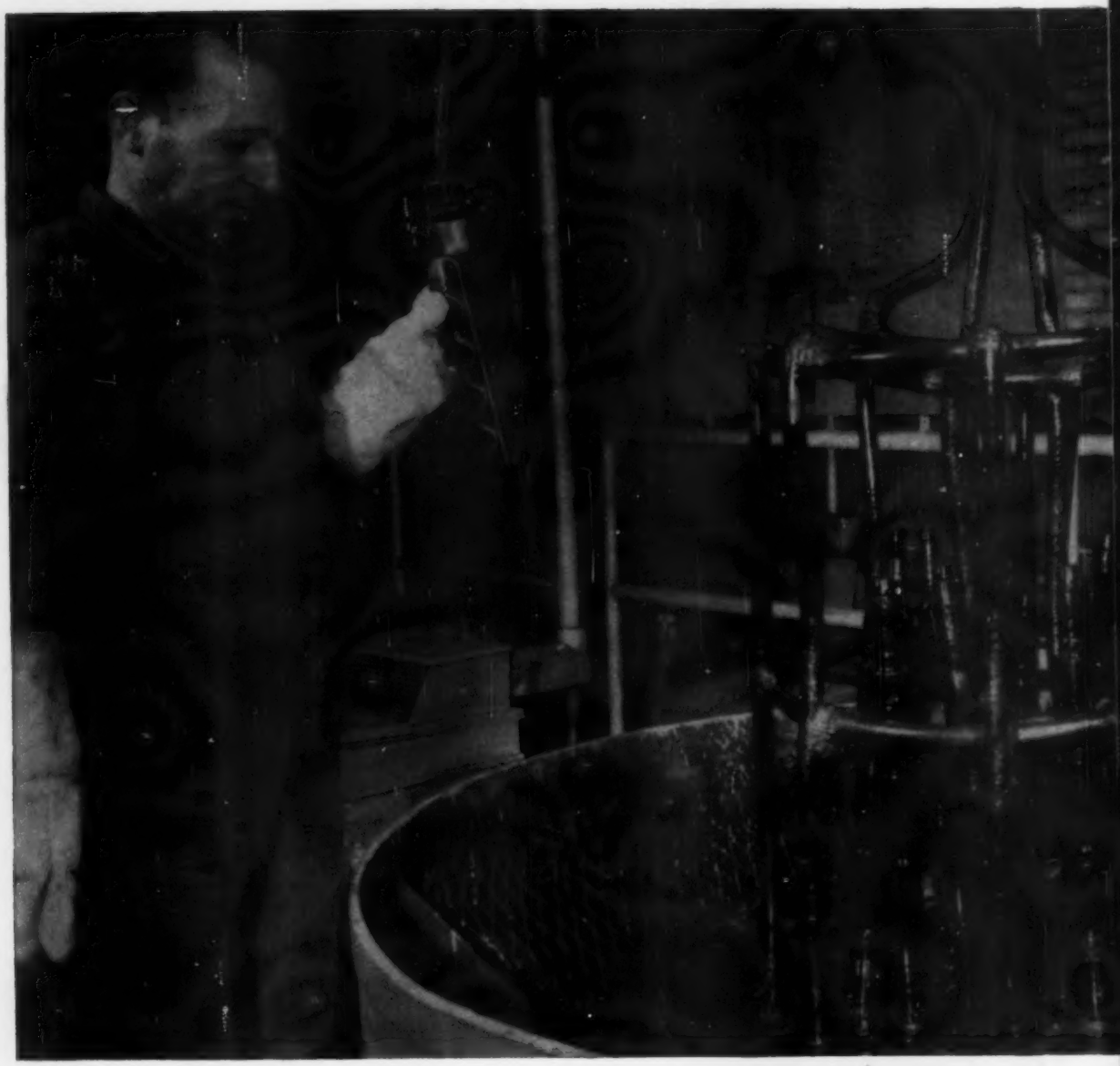


Iron Fireman says:

"We hold difficult worm shafts straight to within

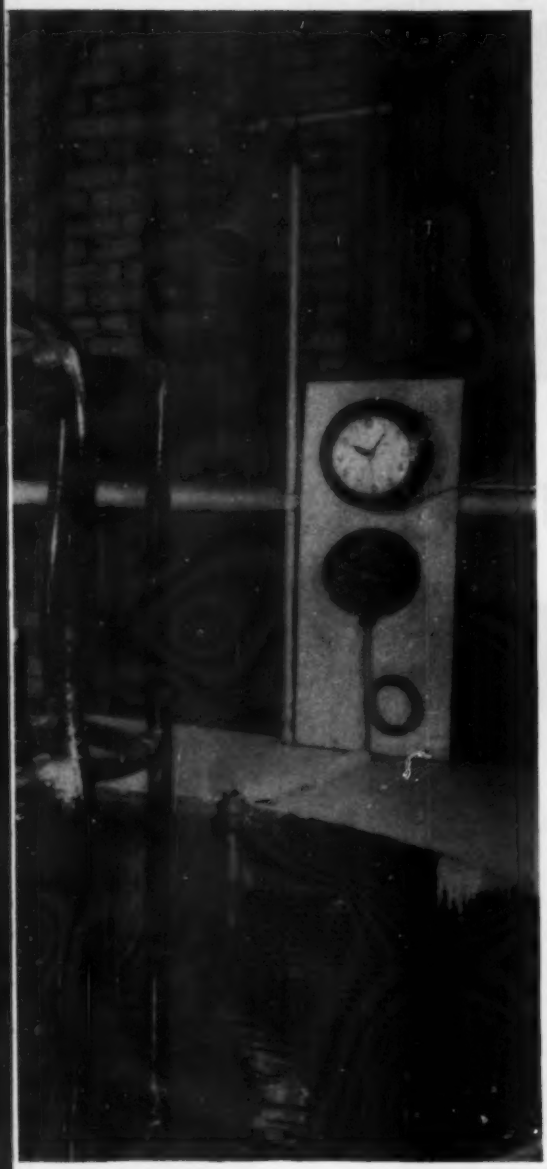
That's the report from Stanley J. Kovac, Chief Production Engineer of Iron Fireman Manufacturing Company, Cleveland, Ohio—makers of the well-known Iron Fireman industrial and domestic oil burners.

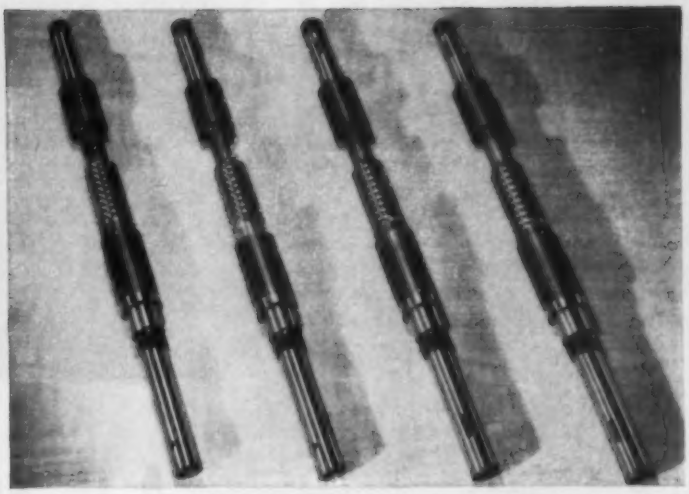
"One of the toughest jobs in our department is the heat treating of worm drive shafts for our industrial furnace units," says Mr. Kovac. "Screw threads and other profile changes in these shafts create many variations in diameter, from 1¾″ down to 1″—setting up the danger of corkscrewing.

"Our maximum out-of-straight limit on these shafts is .030″. But with Gulf Super-Quench in the bath we hold straight to within .020″ on the average. This amounts to considerably less distortion than we experienced before we switched to Super-Quench.

"We not only get less distortion with Gulf Super-Quench," adds Mr. Kovac, "but scale formation is reduced to practically zero, eliminating the need for sand-blasting. We also maintain the required depth and uniformity of hardness."

These excellent results with Gulf Super-Quench can be traced directly to its unique *dual-action* properties





These heavy duty worm shafts, cooled to uniform hardness in Gulf Super-Quench, drive the basic components in Iron Fireman industrial units. Of 5140 steel, they are 23 1/16" long, with diameters varying from 1¾" to 1".

Stanley J. Kovac, left, Chief Production Engineer of Iron Fireman Manufacturing Company, shows T. F. Irving, Gulf Sales Engineer, an Iron Fireman Rotary Oil Burner, in which the components are driven by worm shafts.

One-third less distortion and deeper, more uniform hardening of worm shafts is the payoff with Gulf Super-Quench in this circulating overflow quench bath at Iron Fireman Manufacturing Company, Cleveland, Ohio.

.020" with Gulf Super-Quench"

. . . high initial quenching speed in the critical hardening range . . . slow cooling in the final distortion range.

"The choice of this dual-action quenching oil," says Mr. Kovac, "has paid off in all our heat treating operations, including special contracts for heavy forgings in military applications characterized by extreme changes in mass and section."

How about *your* quenching operations? See how you can cut rejects and increase profits with Gulf Super-Quench. For complete information call a Gulf Sales Engineer at your nearest Gulf office.

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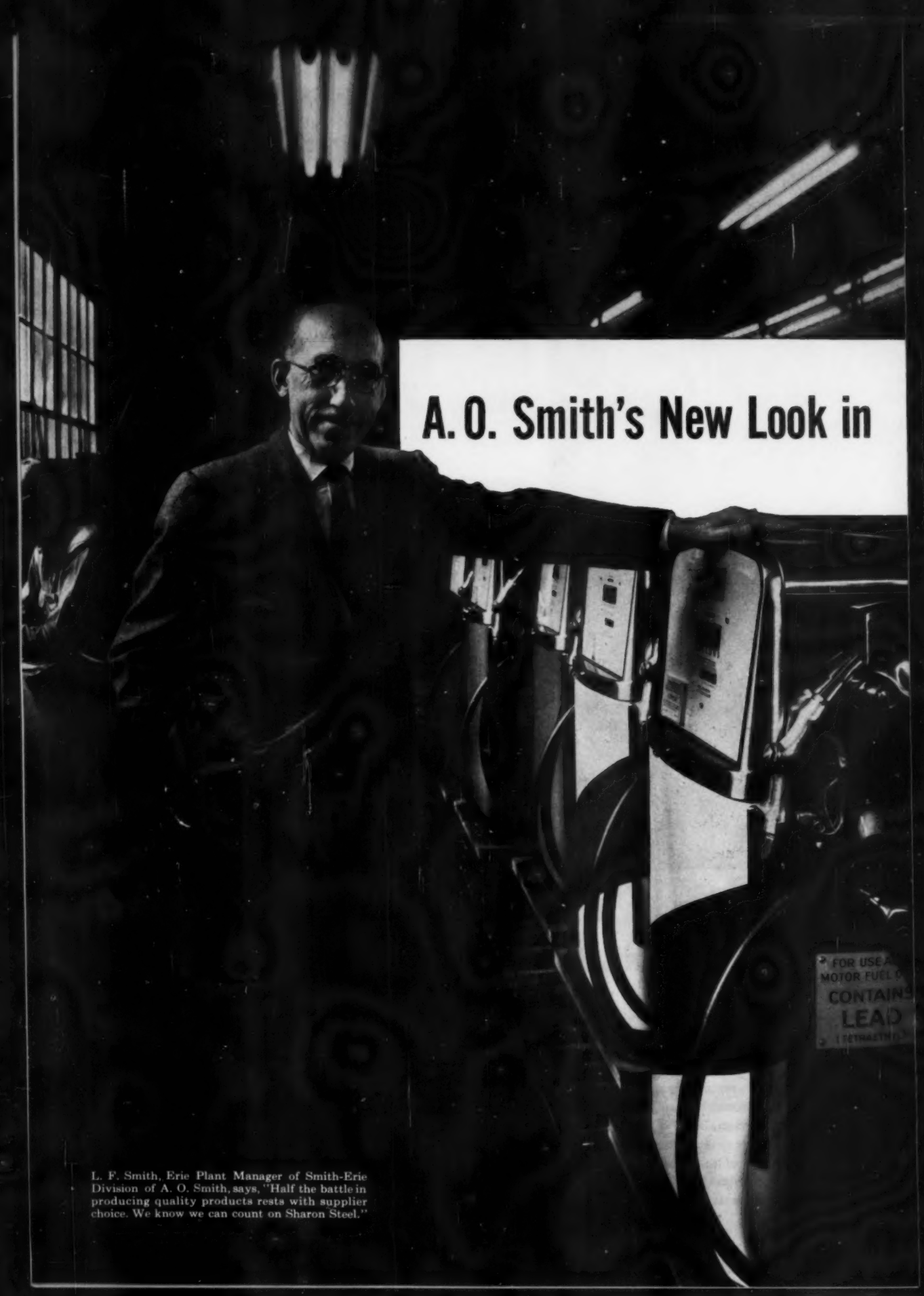

L. F. Smith, Erie Plant Manager of Smith-Erie Division of A. O. Smith, says, "Half the battle in producing quality products rests with supplier choice. We know we can count on Sharon Steel."

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Smith and his Purchasing Agent, J. E. Robison, like Sharon's "Service after Sale" policy. Here they talk shop with Sharon salesman Gordon Garrett.

SHARONSTEEL **SHARON** *Quality* **STEEL**

Tensile Properties of Uranium

Digest of "The Effect of Uranium Hydride Distribution and Recrystallization on Tensile Properties of Uranium", by H. R. Gardner, and S. W. Riches, Preprint No. 127, 1959.

HYDROGEN in the range of 1 to 5 ppm. is a common impurity in uranium. It occurs as a compound – beta uranium hydride – and usually segregates at grain boundaries. The size and number of precipitate particles is a function of cooling rate.

The authors have studied the effect of hydride particle size and distribution on tensile properties in specimens quenched from the beta phase and after a recrystallization anneal in the alpha range. The tensile properties were determined from $+200^{\circ}$ to -20° C. (400 to 0° F.); this includes the range in which uranium experiences a sharp loss in ductility, similar to the ductile-to-brittle transition observed in iron and steel.

The effects of hydride precipitation on the tensile properties of uranium were found to be rather minor and perhaps not important from an engineering standpoint. It should be mentioned, however, that, in this work, composition and heat treating variations were not large. However, there was a significantly higher ultimate and yield strength and lower elongation in samples containing fine hydride particles than was true for samples with no visible hydrides or in samples with coarse hydrides.

Recrystallization of beta quenched uranium by annealing in the alpha range was found to decrease ultimate strength and increased the elongation of samples with and without hydrides.

The temperature at which the ductility decreased sharply was not significantly affected by any of the variables studied and was within the 60 to 93° C. (140 to 200° F.) range for all samples. Below the transition temperature, the tensile strength of samples containing fine hydrides did not decrease as rapidly as it did in samples without hydrides or with coarse hydrides. This is somewhat similar to the effect of carbide particle size on the tensile strength of steel below its ductile-to-brittle transition temperature.

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The RIGHT START . . . a BETTER FINISH

Nuclear Fallout . . .

(*Continued from p.* 145)

50% by 1967 even if no further nuclear weapons are exploded in the open. Individuals may differ by an order of five either above or below this average. Orientals, who get most of their calcium from cereals rather than from milk, have acquired about twice as much Sr^{90} in their bones as Americans.

As in the case of somatic damage, standards cannot set a line on strontium which is "safe" on one side and "dangerous" on the other. Occupational "standards" set for the nuclear industry, where employees willingly accept risks in exceedingly well-regulated plants, can be much higher than in an uncontrolled environment wherein the inhabitant

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has no control. There is also a wide scatter in measured values of strontium in bones due to the variations in diet and numerous other environmental and physiological factors. There is much support for the view

Nuclear Fallout . . .

that *any* radiation above natural background is potentially dangerous to the genes. On the other hand a "permissible" dose should carry a negligible probability of severe genetic injury and one which is acceptable to the exposed individual and to competent medical authorities.* At any rate the maximum permissible body burden for the general population acceptable to the experts in 1957 has been reduced from 100 units to 67 by the 1959 assemblage.

Consequences of future testing were estimated by a panel of 22 experts. They predicted that Sr^{90} would increase in the average human until 1962 to 1965 if no further nuclear devices are tested on the surface or in the atmosphere, at that time reaching 0.007 microcurie per gram of calcium. If the bomb tests of the last five years were repeated at successive 5-year cycles, this figure would go up to 0.012 after the first repetition, and would eventually reach equilibrium (new accessions replacing normal decay) after eight repetitions (40 years) at 0.056 microcurie per g. Ca. This corresponds to three quarters of the maximum body burden for the general population now recommended by the International Commission for Radiological Protection.

Radiation to bone marrow now resulting from the present amount of Sr^{90} will amcunt to 0.3 roentgen in the total life span of 70 years. This increases the radiation exposure over that received from the natural background by 5%. Continuous testing as defined above would bring this figure up to 30%. "Significant" fractions of the population would have bone levels three to five times the average; a few might even have ten times. Continued testing would make the short-lived isotopes more dangerous and also intensify the "hot-spot" problems.

*In this sentence note the undefined (undefinable?) words "negligible", "probability", "severe", "competent".

A Magnetic, Cobalt-Base Alloy

Digest of "Development of a Ferromagnetic Cobalt-Base High-Temperature Alloy", by A. Cochardt, ⓢ Preprint No. 119, 1959.

THIS PAPER reports the development work carried out to produce a cobalt-base alloy which would have the strength of a superalloy but which would be ferromagnetic at the operating temperature and have a high internal damping capacity.

A number of alloys were prepared with cobalt concentrations from 62 to 88%. The nickel content varied from 8.5 to 32.4%. Minor additions of some of the following elements were made to various alloys: titanium, aluminum, silicon, iron, manganese and chromium.

The alloys were tested for damping behavior, aging characteristics, creep and fatigue properties and oxidation resistance. Age hardening curves were determined at 1200, 1300 and 1350° F. for times from 1 to 512 hr. Damping capacity was determined by testing in a torsion pendulum apparatus (or in a Foppl-Pertz tester) between room temperature and 1200° F. A typical curve is shown in Fig. 1. Creep specimens were tested in a lever-type machine at 1200° F., and fatigue testing was carried out in a 120-cycle per sec. electrodynamic fatigue machine. In general, the cobalt-base high damping alloys gave higher rupture times at equivalent stress levels than the present blade material in steam turbines. Figure 2 shows that one of the alloys investigated has a longer rupture time at 1200° F. than A.I.S.I. 403 at 900° F.

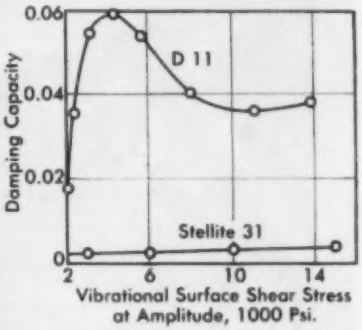

Fig. 1 – Effect of Amplitude on Damping at Room Temperature

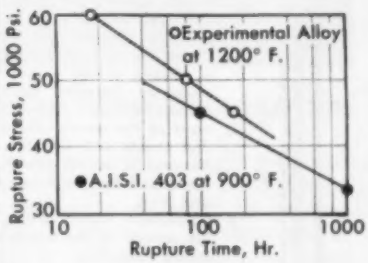

Fig. 2 – Creep Rupture Data

The results of the oxidation tests indicated that the cobalt-base alloys without chromium and silicon were slightly inferior to A.I.S.I. 403, but that the addition of silicon and chromium improved the oxidation resistance so that the alloys were better than A.I.S.I. 403.

As far as strength and damping capacity are concerned, the optimum composition range of the co-

Example: In Type 302, an 18 gauge 36" x 120" sheet has a base price of 52¢ per pound. In sheets of this size, each .001" of thickness weighs 1.26 pounds per sheet. Thus, each .001" of unnecessary thickness costs you at least 65.5¢ more per sheet.

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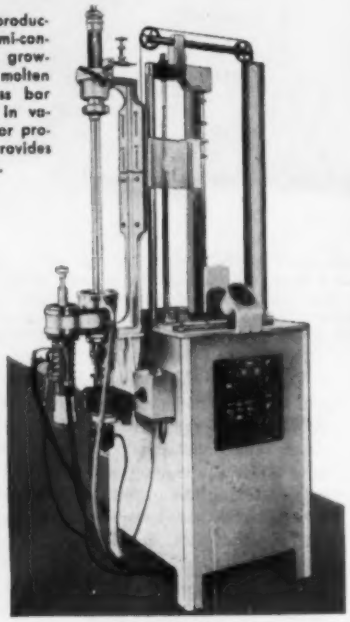

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Co-Base Alloy . . .

balt base alloys studied was 22 to 24% Ni, 1.8 to 2.0% Ti and 0.15 to 0.25% Al. The addition of chromium and silicon improved the oxidation resistance but decreased the damping capacity of the alloys.

W. C. WINEGARD

Fatigue of Steels

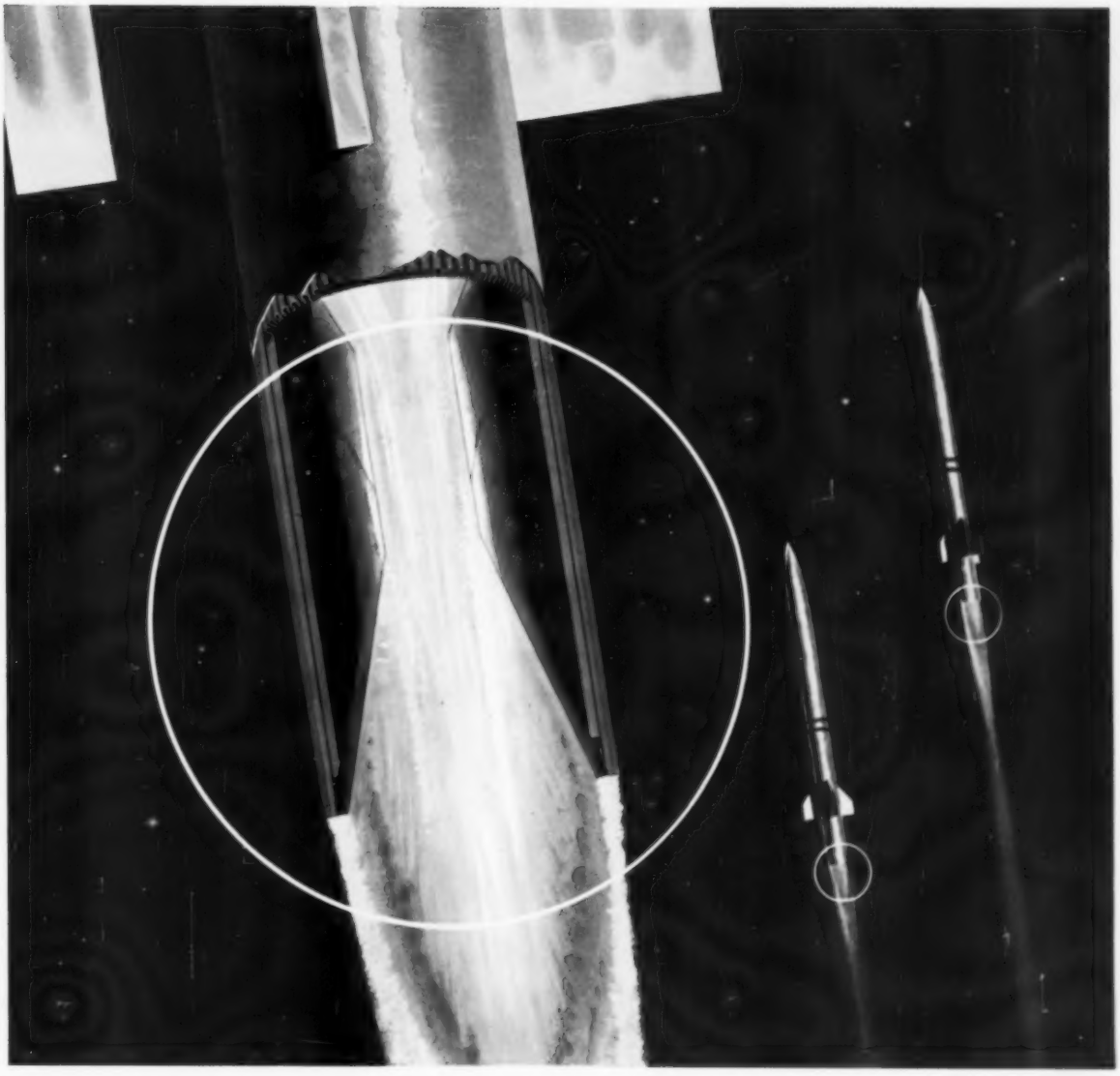
Digest of "Fatigue Properties of High-Strength Steels", by H. E. Frankel, J. A. Bennett and W. A. Pennington, ● Preprint No. 121, 1959.

DESPITE CURRENT widespread interest and extensive research effort on brittle behavior of steels, it remains a fact that the most common cause of mechanical failure of metals in service is fatigue. Although fatigue phenomena have been studied for almost a century, a number of the fundamental metallurgical aspects of the problem still are not well understood. For example, steels which have been heat treated to obtain high static strength levels may or may not have a correspondingly high fatigue strength.

There is general agreement on the superiority of tempered martensite structures with regard to fatigue properties. However, many commercially heat treated steel parts contain products other than martensite. The effect of retained austenite on the fatigue properties of steel is a field in which speculation predominates, and relatively little work has been conducted on it. Other studies have documented results of investigations which variously have shown that retained austenite (*a*) improved, (*b*) had no effect, and (*c*) was detrimental to fatigue strength.

In an effort to resolve some of these conflicting views concerning the role of metallurgical variables on fatigue properties, a well-planned and conducted experimental program was carried out to study the individual and combined effects of carbon content, tempering temperature, hardness, retained austenite, method of cooling for hardening, and refrigeration. The basic assumption used in the design of the program was that alloy content, other than carbon, was not as important as

(*Continued on p.* 264)



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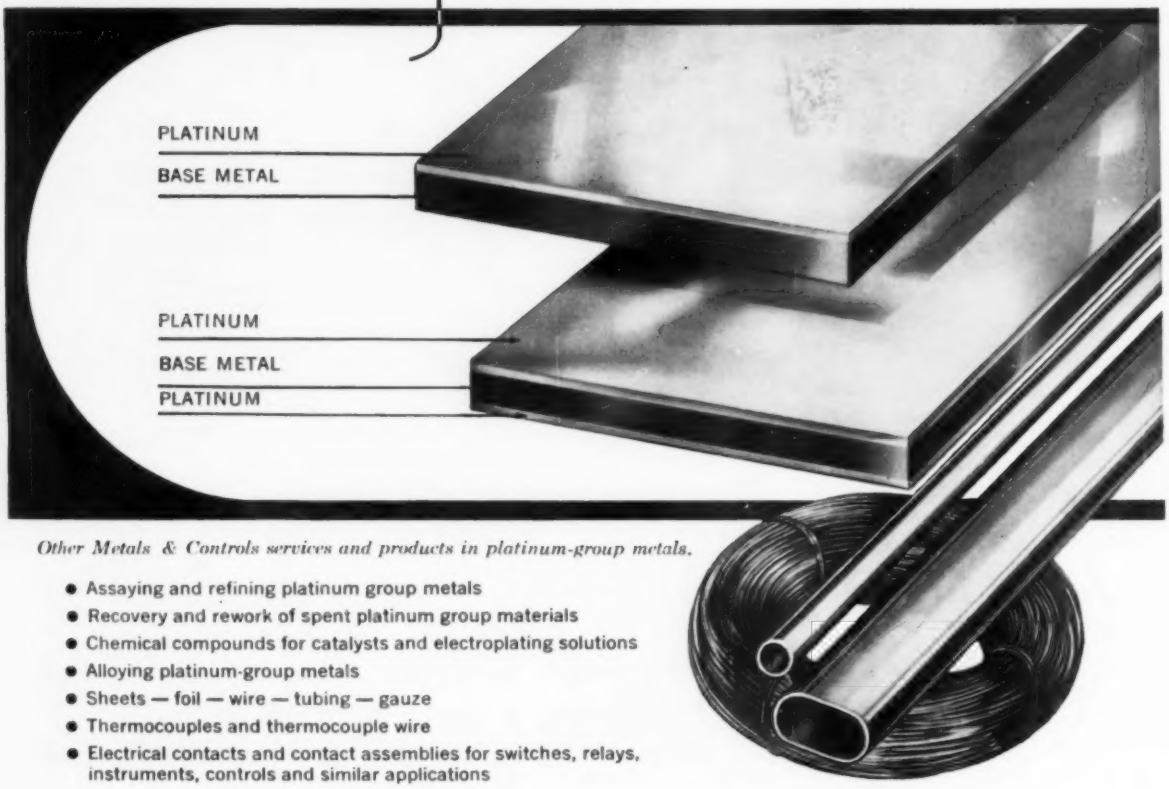

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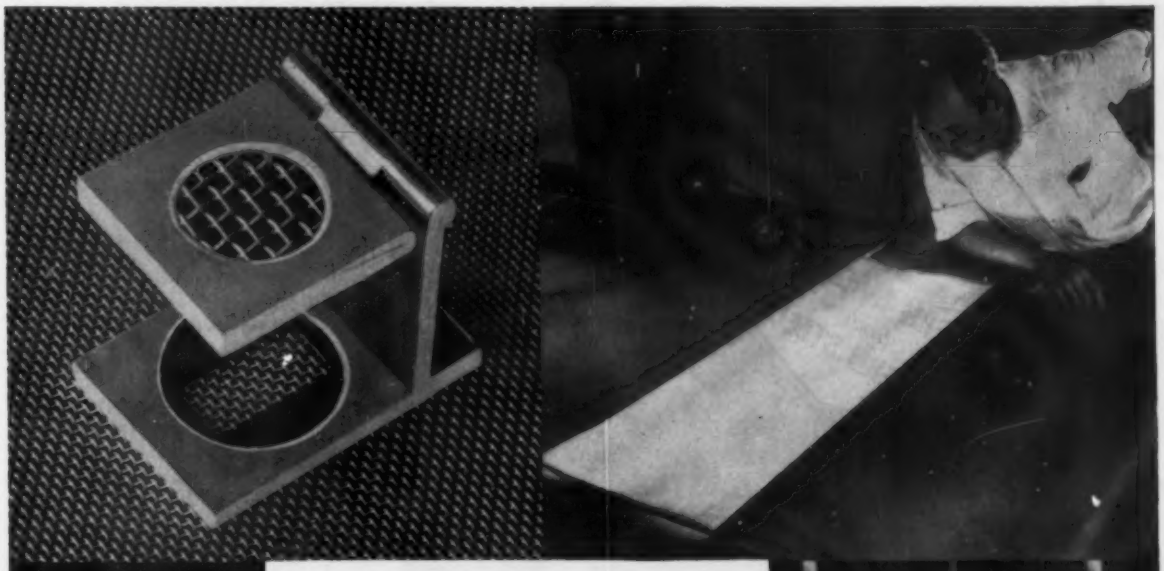
Fatigue of Steels . . .

microstructure in the determination of fatigue strengths. The materials used were obtained from commercial heats of S.A.E. 4340 and 52100 steels and two common grades of carbon toolsteels. All tests were conducted on R. R. Moore, rotating beam, fatigue testing machines. After preliminary work to determine the effects of variables in specimen preparation, all specimens were prepared by a careful technique developed to obtain a reproducible surface finish with minimum induced residual stress or alteration of metallurgical characteristics.

Various heat treatments were used to obtain a quenched and tempered structure containing varying amounts of retained austenite and carbides, but with fairly constant fine austenitic grain size. Both direct quenching and "marquenching" techniques were employed. Some specimens were refrigerated after quenching, and the effects of single and double tempering treatments were investigated also.

The results of this study showed conclusively that an increase in retained austenite decreases the fatigue strength of the materials. However, for steels with over 0.60% C, there appears to be a limiting value beyond which there is no further decrease in fatigue strength accompanying increased amounts of retained austenite. Removal of retained austenite, which was accomplished in this investigation by refrigeration treatment, tends to increase fatigue strength. Further study of this effect provided conclusive evidence not only that retained austenite is transformed to martensite by fatigue stressing, but also that the extent of the transformation is a function of the stress amplitude.

An important contribution of the work is affirmation of the validity of the basic assumption that alloying elements, other than carbon, are not as important as microstructure in their effect on the fatigue strength. By analyzing the test data to isolate the effect of carbon content, it is shown that, as carbon content is increased, a higher hardness is necessary for equivalent fatigue strength. This relationship is illustrated by a curve obtained from determination



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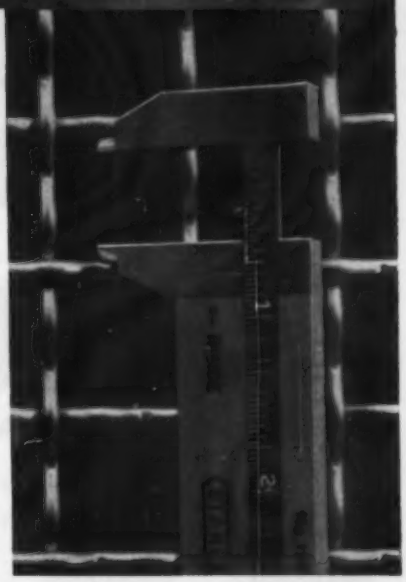

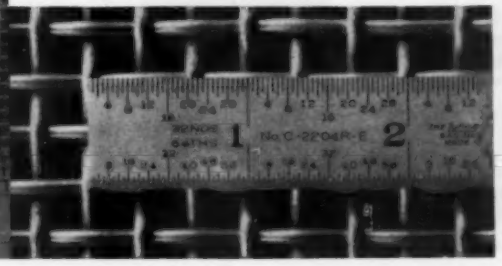

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Fatigue of Steels . . .

of the hardness necessary to attain a fatigue strength of 150,000 psi. with 0% retained austenite, for the four steels tested.

On the basis of the observations of this study, it is hypothesized that the large localized stresses resulting from an austenite-martensite reaction may nucleate submicroscopic cracks that lower fatigue strength of a steel. The transformation of retained austenite, either by thermal or mechanical treatments prior to cyclic stressing, improves fatigue properties. Mechanical treatment (for example, shot-peening) has an additional effect in that favorable compressive stresses are introduced at the surface with further benefit to fatigue properties.

It is thus apparent that to obtain optimum fatigue properties of heat treated high-strength steels, positive steps must be taken to avoid or remove retained austenite in the microstructure. G. H. ENZIAN

Trace Elements in Nickel

Digest of "The Effect of Trace Elements on the Tensile, Electrical Resistance and Recrystallization Properties of High-Purity Nickel", by K. M. Olsen, Preprint No. 130, 1959.

THIS PAPER describes the effects of small quantities of magnesium, aluminum, manganese, silicon, boron, carbon, zirconium, cobalt, tungsten and titanium on the electrical resistance, tensile and recrystallization properies of nickel. Such a study is of practical importance because of its application to the operating life of nickel cathode structures which are used in vacuum tubes.

Measurements were made on 0.025-in. diameter wire which had been cold drawn 70% reduction in area and heat treated at various temperatures under dry hydrogen or helium. Ingots were obtained by melting sintered carbonyl nickel slugs under a controlled program of hydrogen, vacuum, and helium atmospheres. These were hot rolled into slabs from which 7/16 × 7/16-in. bars were cut. The 0.025-in. wire was produced by a series of swaging, annealing (1500° F.) and drawing

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Trace Elements . . .

steps. Except for controlled additions, all impurities were found to be below 0.005% by weight for any single element.

Results are presented in groups of curves in which elongation, tensile strength and resistivity are plotted against annealing temperature. Groups are representative of elements which exhibit much solid solubility in nickel (cobalt, manganese, and tungsten), those with limited solubility (silicon, titanium and aluminum) and those with very limited solubility (carbon, magnesium, boron and zirconium).

Additions of tungsten, titanium and silicon had the greatest effect on the resistivity of nickel. For recrystallized material, 0.2 wt.% W increased resistivity from 0.622 to 0.672 ohm-g. per sq.m., a 0.088% Ti addition from 0.622 to 0.668, and 0.1% Si addition from 0.622 to 0.684. Zirconium and carbon had the greatest influence on tensile strength. In the cold worked condition, 0.11% Zr increased ultimate tensile strength from about 100,000 to 120,000 psi., while an 0.11% C addition gave an increase to 140,000 psi.

The most pronounced influence on recrystallization was found to be associated with additions of elements which had a much larger atom size than that of nickel. Zirconium resulted in the greatest retardation. An 0.11% Zr addition produced an approximate 720° F. increase in recrystallization temperature (from about 720° to about 1440° F.).

W. R. Opie

Temper Brittleness of Steel

Digest of "Correlation Between Internal Friction and Temper Brittleness in Steel", by Abdul-Fattah K. Kaddou and P. C. Rosenthal, ⊖ Preprint No. 151, 1959.

AT THE PRESENT TIME, no satisfactory theory has been evolved to describe the basic mechanism of temper brittleness. The authors have used internal friction tests to study the influence of carbon on temper brittleness in a plain carbon

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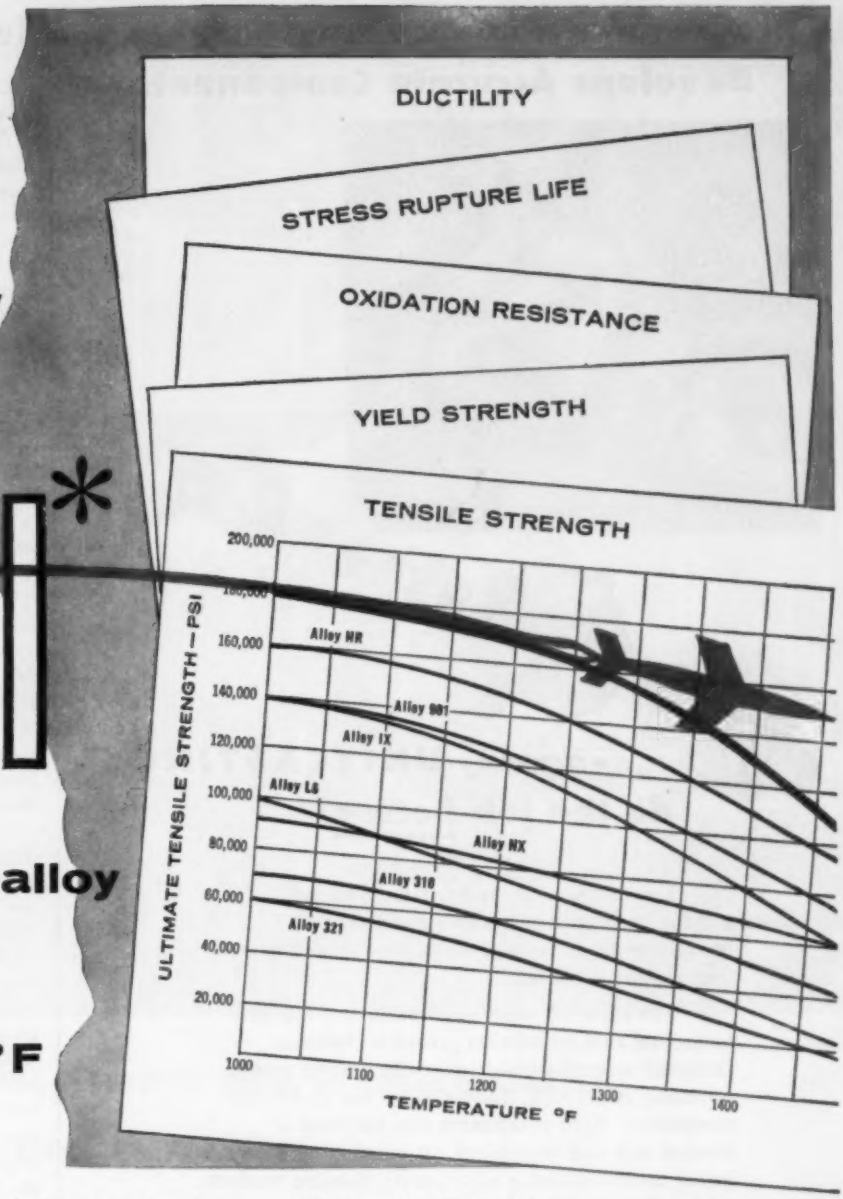

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Temper Brittleness . . .

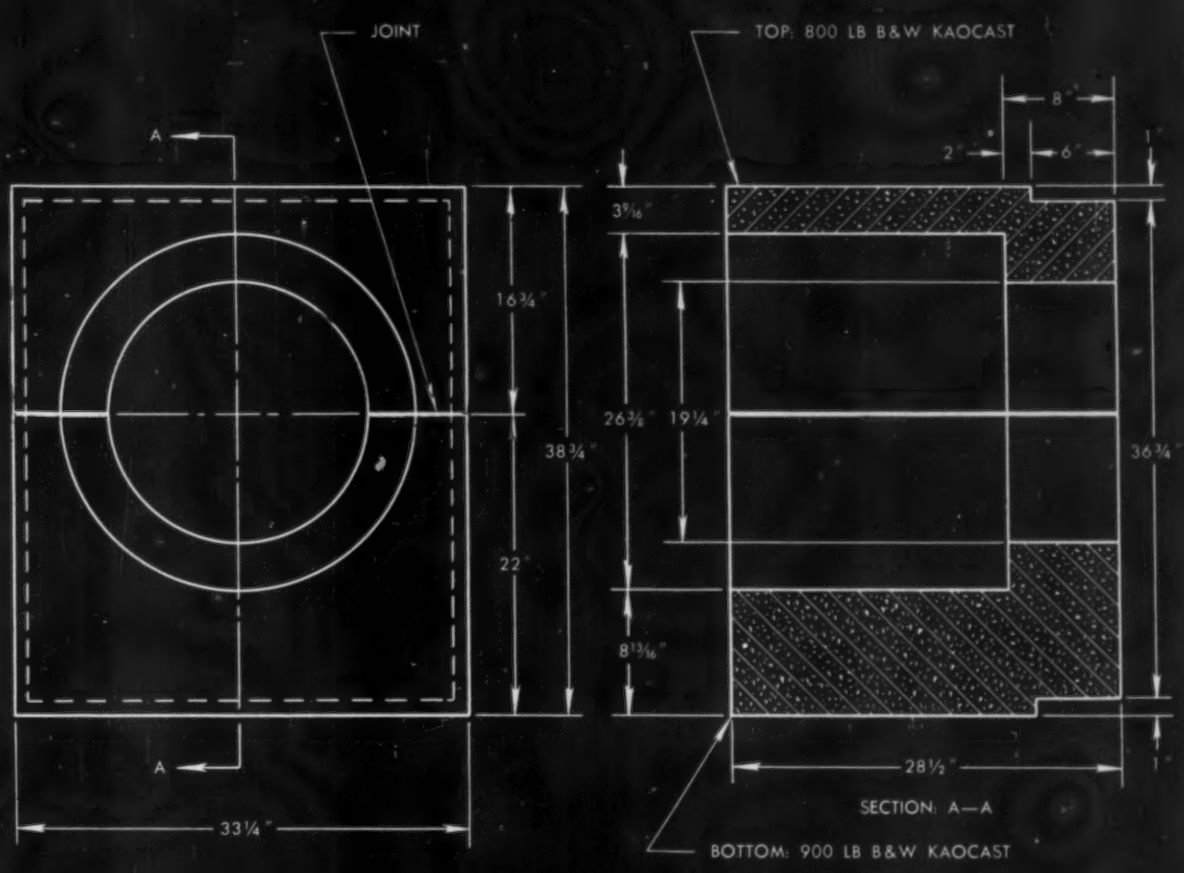
(A.I.S.I. 1016) and susceptible alloy steel (A.I.S.I. 3310).

The basic feature of the test is that an internal friction peak has been found at temperatures near room temperature and at frequencies of about 1 cycle per sec. This peak has been ascribed to the stress-induced interstitial diffusion of the solute atom in alpha iron. By measuring this peak, it is possible to study the concentration and segregation of carbon in ferrite.

Wire specimens from both steels were austenitized 1 hr. at 1700° F. (925° C.) in a neutral salt bath, then water quenched. A group of A.I.S.I. 3310 specimens was tempered 1 hr. at 1150° F. (620° C.) in a helium atmosphere, then water quenched. The specimens thus treated were considered "tough." Some of these specimens were further tempered 50 hr. at 930° F. (500° C.) for embrittlement. To study the reversibility of temper embrittlement, some of the embrittled specimens were retempered 1 hr. at 1150° F. (620° C.) which is above the embrittling range. Another group of the A.I.S.I. 3310 specimens were tempered 1 hr. at 1250° F. (675° C.), then water quenched. Some of these specimens were given an additional tempering of 48 hr. at 900° F. (480° C.) for temper-embrittlement.

The A.I.S.I. 1016 specimens had an initial temper of 1 hr. at 1150° F. (620° C.), then an additional temper of 65 hr. at 930° F. (500° C.) for embrittlement. Charpy V-notch impact tests were carried out on substandard test pieces prepared from the A.I.S.I. 3310 steel after tempering 1 hr. at 1150° F. (620° C.) and water quenching, and after an additional tempering treatment of 65 hr. at 930° F. (500° C.), followed by water quenching.

The internal friction results of the tough A.I.S.I. 3310 steel showed two peaks in the logarithmic decrement-temperature curve, one at about room temperature and the other at 430° F. (220° C.) Upon embrittlement the internal friction results were different. The two peaks had disappeared and the background damping was reduced to half that for the tough steel. The A.I.S.I. 3310 steel samples, embrittled and then retempered at 1150° F. (620°



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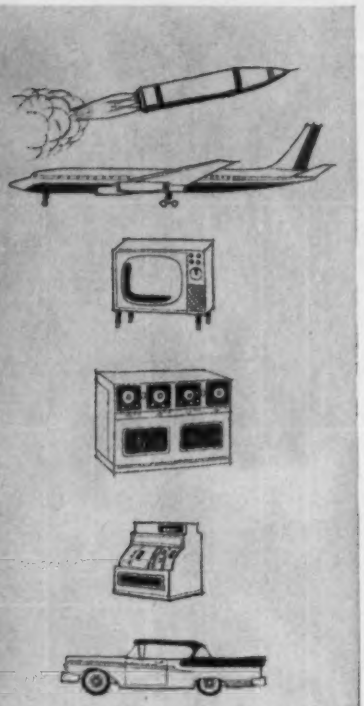

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Temper Brittleness . . .

C.), showed a curve similar to that of the tough steel. The internal friction curves for the A.I.S.I. 1016 steel showed the room-temperature peak for the initial tempering treatment (1150° F. [620° C.] for 1 hr.) to be very pronounced, whereas the 430° F. (220° C.) peak is not evident. The internal friction curve of the double-tempered A.I.S.I. 1016 steel is different from the curve of the embrittled A.I.S.I. 3310 and shows only a decrease in the room-temperature peak without the complete disappearance as evidenced in the alloy steel. Furthermore the background damping is unchanged.

The results of impact tests on the tough and embrittled A.I.S.I. 3310 steels showed a shift of transition temperature from −47 to +162° F. (−44 to +72° C.)

The room-temperature peaks in the damping curves may be explained by the dissolved interstitial carbon and nitrogen atoms in ferrite. Since the peaks disappear in the brittle condition, the embrittling temperature is apparently in the vicinity of the critical temperature for establishing condensed Cottrell atmospheres around dislocations. When this occurs, stress induced atom movement cannot occur because the solute atoms are locked into position. Furthermore, due to the strong anchoring force of the atmospheres to the dislocations, the background damping is reduced. It is concluded that temper embrittlement corresponds to the formation of condensed atmospheres at the dislocations, rendering these dislocations inoperative under certain conditions of loading and testing temperature.

The 430° F. (220° C.) peak is directly related to the solute atoms of carbon or nitrogen or both, since both the room-temperature and the 430° F. (220° C.) peak disappeared after embrittlement. Upon retempering the embrittled steel, the condensed atmospheres are destroyed; this may explain reversibility of tempering embrittlement.

The intergranular fracture of a temper-brittle steel occurs because the dislocations are anchored very strongly. They cannot move when loaded and the fracture path, therefore, follows the grain boundary.

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Iron-Aluminum Alloys

Digest of "Structure and Properties of Austenitic Alloys Containing Aluminum and Silicon", by D. J. Schmatz, ⊕ Preprint No. 160, 1959.

DURING the past several years, there has been an increasing interest in the development of oxidation resistant alloys from nonstrategic elements. The corrosion resistant characteristics of iron-aluminum alloys are particularly attractive and have led to the investigation of several iron-aluminum base ternary alloys, the most promising of which were in the Fe-Al-Mn and the Fe-Al-C systems. The information available about these systems led to the investigation of the Fe-Al-C-Mn and Fe-Al-C-Mn-Si alloys reported here.

Quaternary alloys were made by adding aluminum to vacuum melts of iron and carbon, introducing helium into the melting chamber, and then making the manganese addition. The following composition ranges were investigated: 7 to 13% Al, 20 to 40% Mn, 0.10 to 1.0% C. The melts were cast in 2½-in. round ingots and subsequently hot rolled to ⅝-in. rod. Tensile tests were made at various temperatures up to 1500° F. Metallographic examinations were made of these alloys in both the quenched and slow cooled conditions to determine the relative amount and stability of the austenitic phase.

Table I – Quench Aging of Experimental Fe-Al Alloy

Treatment	Tensile Strength	Yield Strength	Elongation	Reduction in Area
As-quenched	120,000 psi.	82,000 psi.	72%	70%
Quenched and reheated to 1100° F.	168,000	153,000	25	45
Slow cooled	156,000	134,000	16	16

The data suggested that an iron-base alloy containing 9% Al, 30% Mn and 1.0% C might exhibit near optimum high-temperature strength properties and oxidation resistance for this system. At constant manganese and aluminum, strength properties improve with carbon content between 0.1 and 1.0%. At constant managenese and carbon, the oxidation resistance and strength improved with increasing aluminum from 5 to 9%. Above 9% Al, the alloy was not completely austenitic and exhibited a resultant loss in ductility. A decrease to 20% Mn resulted in an increased instability of the austenitic structure.

Efforts to produce a higher strength austenitic alloy (iron base with 13% Al, 40% Mn, 1.0% C) were unsuccessful. This material was extremely brittle after slow cooling indicating that transformation had occurred. Metallographic examination confirmed the appearance of a new brittle phase.

A group of quinary alloys were processed in the same manner as the first group using Fe, 9% Al, 30% Mn, 1.0% C as a base to which small amounts, usually less than 3%, of other elements (chromium, nickel, boron, silicon, nitrogen, titanium, molybdenum) were added. Tensile properties were measured, oxidation resistance was noted, and a metallographic examination was made to determine the effect of the added element upon phase relationships and stability. Only silicon improved both the oxidation resistance and

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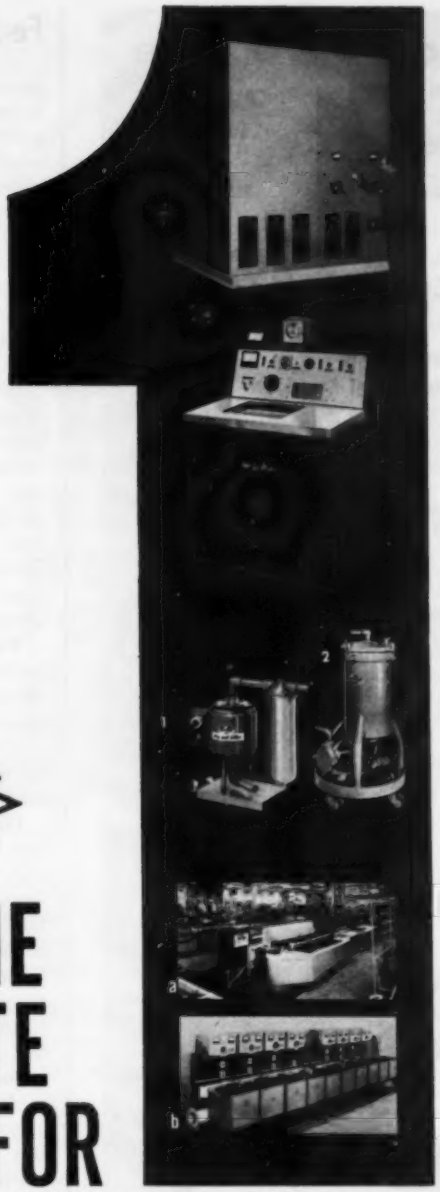

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Fe-Al Alloys . . .

strength properties without drastically impairing ductility. In the temperature range of 1200 to 1350° F., where this alloy exhibited good oxidation resistance, the data indicated an optimum silicon content of 1.5%. This addition had little effect upon the room-temperature properties of the alloy, but at 1200° F. it resulted in increases in tensile strength from 58,000 to 97,000 psi., and in yield strength from 43,000 to 78,000 psi. with a corresponding reduction in elongation from 27 to 5% and reduction in area from 30 to 9%. At this temperature, an increase in silicon above 1.5% causes an almost linear increase in strength properties with only slight additional loss in ductility. However, at 1350° F. there is a distinct maximum in the strength values at 1.5% Si.

The strength properties of this alloy may be improved by quench aging as shown in Table I. These tests were completed at room temperature and the validity of these treatments for elevated-temperature service has not been evaluated.

Oxidation resistance of these alloys is attributed to aluminum and may be improved by increasing aluminum content or by decreasing carbon or manganese. Metallographic studies of these alloys revealed a thin ferritic surface layer which the author suggests is an aluminum-iron binary caused by a loss of carbon and manganese. This binary is known to form a highly impervious oxide film which the author indicates may be developed by a "pre-oxidation" treatment at a temperature above the expected test or service temperature.

Silicon additions up to 2.5% had little effect upon the phase relationships. Silicon may act as a solution strengthener in both ferrite and austenite. Schmatz and Zackay have previously shown that a 9% Al, 1.5% Si-iron ferritic ternary alloy is stronger at elevated temperatures than a 9% Al-iron alloy. The author proposes that, in this quinary alloy, the silicon may strengthen any grain-boundary ferrite formed during aging or modify the quantity, type and dispersion of the carbides formed during aging.

The author concludes that the 9% Al, 30% Mn, 1.0% C, 1.5% Si-iron

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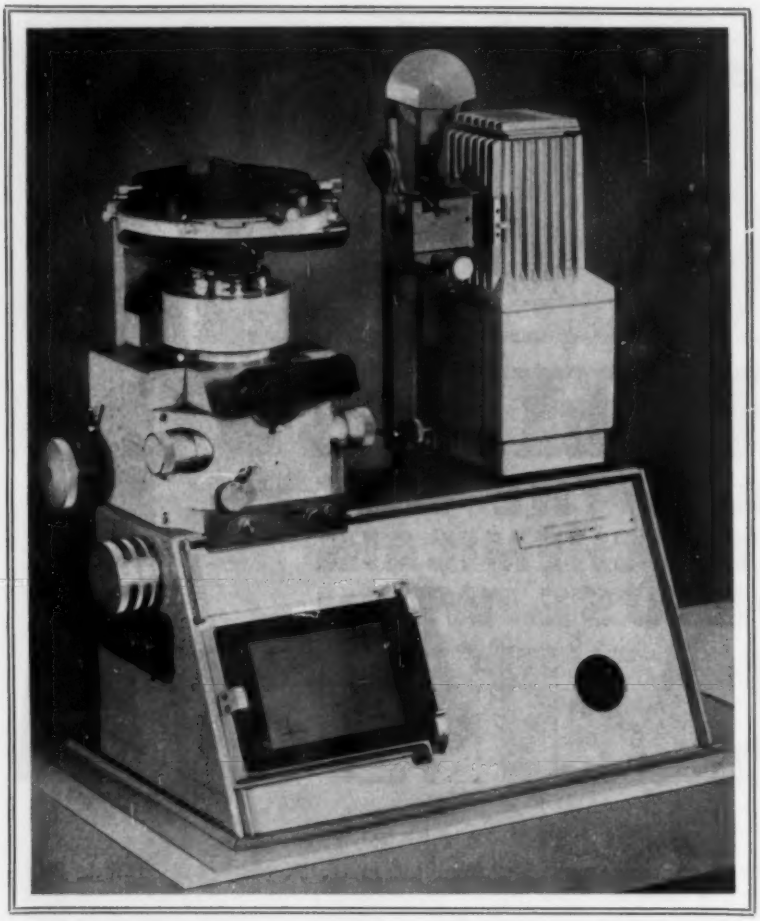

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Magnetic Properties of 3.5% Cr Steel

Digest of "Effect of Cooling Rate From M_s Temperature to Room Temperature on Magnetic Properties of 3.5% Chromium Magnet Steel", by W. L. Hodapp and E. A. Loria, Preprint No. 122, 1959.

THE RATE of cooling from the M_s temperature to room temperature exerts considerable influence on the magnetic properties of 3.5% Cr magnet steel. This investigation reports the results of the effect of cooling rate as well as the effect of stabilizing treatments on magnetic properties of this steel.

The steel used is a common grade for permanent magnets. It has a composition of about 0.9% C, 3.6% Cr, 0.5% Mn, 0.2% Ni. Heat treatment consisted of austenitizing, quenching into salt at 500° F. (M_s = 435° F.), holding for 1 min., and cooling at different rates to room temperature. Little or no bainite formed during the hold at 500° F. The four rates used were those obtained by cooling in water, oil, air or furnace. In addition, stabilization treatments were used following cooling to room temperature; these treatments consisted of combinations of tempering 5 hr. at 212° F. and cooling for 24 hr. in dry ice. In addition to magnetic properties, some measurements or retained austenite were made.

As the cooling rate from 500° F. decreases, the magnetic properties change as follows: the maximum magnetic flux density (B_{max}), the residual magnetism (B_{res}), and the maximum energy product (EP_{max}) decrease, while the coercive force (H_c) increases. X-ray measure-

(*Continued on p. 282*)

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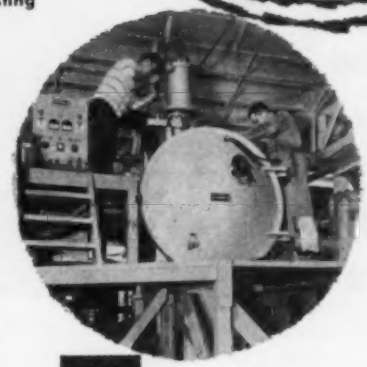

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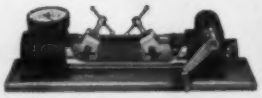

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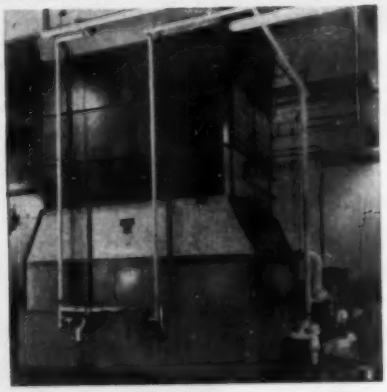

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Cr Steel . . .

ments showed that water quenching gave 3% retained austenite (R_φ), oil gave 4% R_γ, air 7% R_γ and furnace cooling 9% R_γ. The authors believe that the changes in magnetic properties with cooling rate are directly associated with the retained austenite.

Stabilization treatments produced negligible changes in the magnetic properties of the water quenched samples. However, as the cooling rate decreased, stabilization had an increasingly greater effect, the effect being to change the properties in such a direction as to make them more nearly equal to the quenched samples. Except for the maximum energy product, the magnetic properties of the three slowest rates still differed considerably from the water quenched samples even after a treatment of tempering + cooling + tempering + cooling. No retained austenite measurements are reported following the stabilization treatments.

As the austenitizing temperature is increased from 1500 to 1550° F., H_c becomes relatively insensitive to stabilization treatments, while the other magnetic properties still are capable of being changed considerably. This behavior may be associated with increased solution of alloy carbides at the higher austenitizing temperature. (Carbides formed about 10% of the structure at 1500° F.)

Samples isothermally transformed to bainite at 500° F. showed a higher B_{res} and a lower H_c and EP_{max} than those treated in the normal manner. In addition, the magnetic properties of bainite were insensitive to stabilization treatments. F. E. WERNER

Oxidation of W-Cb Alloys

Digest of "The High Temperature Oxidation of Tungsten-Columbium Alloys", by J. W. Semmel, Jr., Preprint No. 161, 1959.

THE AUTHOR of this paper reviews the existing literature describing the oxidation behavior of tungsten up to 2300° F., and describes briefly the results of an exploratory study of binary alloys of tungsten with cobalt, titanium, zirconium, tantalum, chro-

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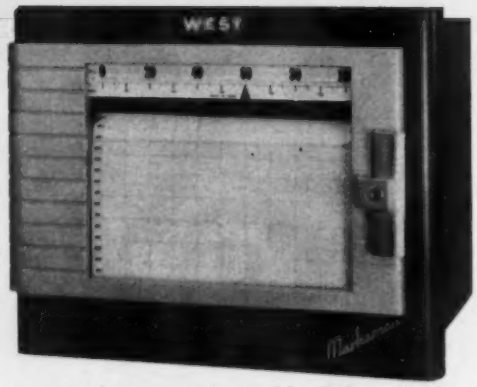

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W-Cb Alloys . . .

mium and molybdenum. Concluding that alloys with columbium and with tantalum warranted further investigation, the author selected columbium as representative of the probable chemical behavior of both.

Earlier investigations of the oxidation of tungsten up to 1850° F. established the presence of a continuous inner oxide and a porous outer oxide, resulting in oxidation beginning parabolically and eventually becoming linear with respect to time. Extension to higher temperatures showed similar behavior up to 2100° F., but only parabolic oxidation at 2300° F. This change in oxidation behavior was attributed to melting of the outer oxide layer to form a semiprotective liquid layer at the higher temperatures. The present investigation using alloys was designed to develop solid oxide layers and slower oxidation at the higher temperatures.

The alloys resulting from efforts to produce 10 at.% additions of cobalt, titanium, zirconium, vanadium and chromium were not particularly suitable, and did not show promising oxidation characteristics. An alloy containing 10 at.% Mo formed a liquid oxide at 2000° F. Alloys with columbium and tantalum produced solid oxides at 2300° F.

Tungsten alloys containing from 0.25 to 95 at.% Cb were prepared and oxidized in flowing dry air for periods of time from 1 to 6, 8 or 20 hours. Hardness changes in the alloys were determined after oxidation for 1 hr. at 2000° F. The extent of oxidation was determined by measuring thickness changes. The structures of the oxide layers were examined microscopically and by X-ray diffraction.

Tungsten alloys containing 2.5 to 10 at.% Cb oxidized more slowly than unalloyed tungsten at 2000° F. At 2000° F. the oxidation is primarily linear with respect to time but is parabolic at 2300° F. Alloys with more than 15% Cb oxidize parabolically at both 2000 and 2300° F.

X-ray and microscopic examination indicate no significant difference in the oxide structures on the alloys which oxidize linearly at 2000° F. and parabolically at 2300° F., but the oxide formed at 2300° F. is harder and more dense. The struc-

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W-Cb Alloys . . .

tural similarity and the densification at higher temperatures indicate a sintering of the oxide and consequent reduction in porosity of the outer layer, or deformation of the oxide and stress relaxation, as possible causes of the transition to parabolic oxidation. The oxide which forms parabolically at both 2000 and 2300° F. on the 20% alloy, has a different and complex structure, not yet identified, from the oxide which forms on the 10% alloy.

Limited hardness measurements conducted in the investigation indicate that alloys with less than 50% Cb behave more nearly like tungsten, in that they are not greatly hardened or embrittled by absorption of gases during oxidation at 2000° F. for periods of an hour. The higher columbium alloys, like columbium, appear to be more drastically hardened. In some alloys, this hardening is more serious than the scalding.

E. C. MILLER

Creep of Aluminum

Digest of "Effect of Stress on the Creep of Aluminum in the Dislocation Climb Range", by A. E. Bayce, W. D. Ludemann, L. A. Shepard and J. E. Dorn, ● Preprint No. 137, 1959.

PREVIOUS WORK from this same laboratory has shown that the creep of pure aluminum is controlled by different thermally activated processes depending upon the temperature of test. Over 425° F., activation energy for creep of aluminum remains constant at 35,500 cal/mole up to the melting point. The coincidence of this activation energy with the estimated activation energy for self-diffusion of aluminum, and the extensive polygonization that occurs during creep in this temperature range lead to the conclusion that the creep process under these conditions is controlled by the rate of climb of dislocations. In this paper, the authors have extended our understanding of the creep process by determining the effect of stress on the creep rate in this region.

The problem was attacked by performing creep tests on pure aluminum at temperatures greater than

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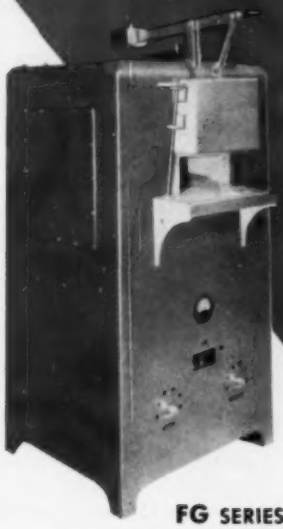

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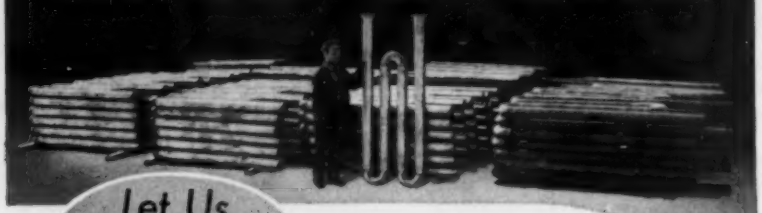

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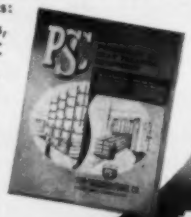

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Creep of Al . . .

425° F. The effect of stress was then determined by increasing and decreasing the stress abruptly during the course of primary creep at each of several temperatures. The results of such tests show that barriers introduced during the course of primary creep cause the creep rate to decrease continuously until a steady-state pattern of barriers is obtained under secondary creep. These barriers may be of two kinds: (*a*) recoverable Lomer-Cottrell dislocations, and (*b*) stress interaction barriers between dislocation arrays on parallel planes. Furthermore, the creep rate is not a simple function of stress; it depends also on the structure, the dislocation pile-up in arrays and the distribution of barriers. Upon a large decrease in stress, the creep rate has initially a high value $\dot{\varepsilon}_1$ which subsequently reduces to a first constant rate $\dot{\varepsilon}_2$ as the arrays thin out by climb, and then increases to another rate $\dot{\varepsilon}_R$, the secondary creep rate for the reduced stress as the original barriers recover and are replaced by new, more widely spaced barriers.

Thus, it may be concluded that a simple functional relationship between creep rate and stress does not exist; the effect of stress on the creep rate depends on the structure as well as the stress. In general, the creep of aluminum under conditions of changing stress can be resolved only qualitatively in terms of the dislocation climb models of creep.

T. E. LEONTIS

Flow and Fracture of Vanadium

Digest of "The Flow, Fracture and Twinning of Commercially Pure Vanadium", by W. R. Clough and A. S. Pavlovic, Preprint No. 125, 1959.

IN THIS INVESTIGATION, some of the flow and fracture characteristics of commercially pure vanadium were compared with those of other body-centered cubic metals.

Vanadium was initially prepared by bomb reduction of V_2O_5 with calcium, and was found to contain up to 0.047% C, 0.070% O and 0.081% N. No oxides or nitrides

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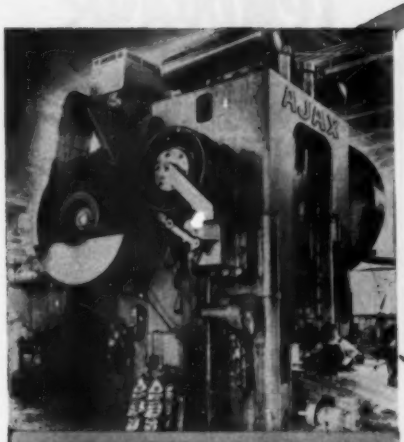

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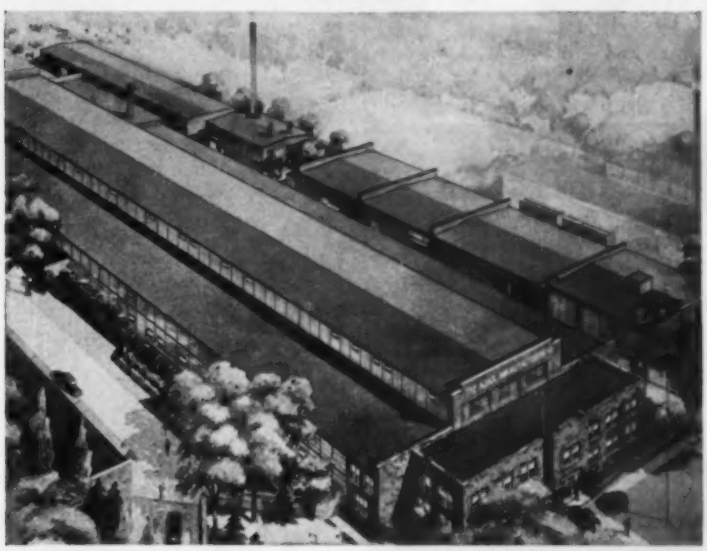

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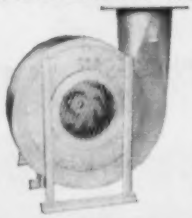

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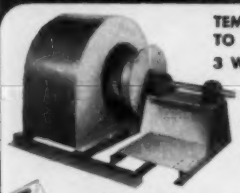

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Vanadium . . .

were found, but V_2C was present as a second phase in all specimens.

Tensile tests were carried out between 200° C. (390° F.) and −196° C. (−320° F.); there was a fivefold increase in yield strength, a threefold increase in tensile strength, and a ductile-to-brittle transition as the temperature was lowered. The variation in yield stress with testing temperature is shown in Fig. 1. It was found to obey the same relationship as the low temperature data

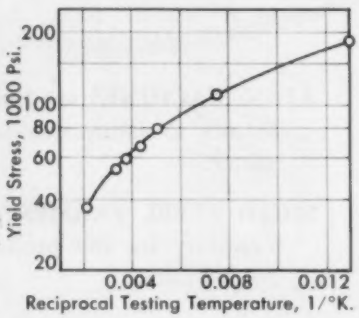

Fig. 1 — Effect of Testing Temperature on the Yield Stress of Vanadium

for iron and molybdenum. The ductile-to-brittle transition is clearly shown in Fig. 2 where the Charpy V-notch energy figures are plotted against the testing temperature. Transition temperature is 130° C. (260° F.)

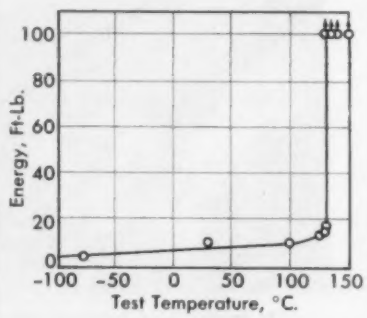

Fig. 2 — Charpy V-Notch Energy Transition Curve

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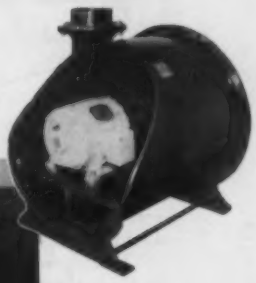

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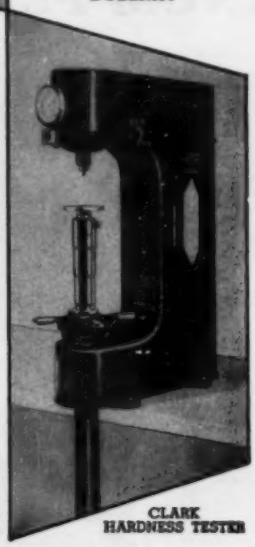

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Vanadium . . .

planes, and the nature of fracture is discussed in terms of these cleavage planes.

The paper contains a number of observations on mechanical twinning at low temperatures. While direct X-ray evidence is not presented, the authors conclude that twinning occurs on the {112} plane. Several reasons are advanced for this postulate, and a general discussion of twin formation is given. No yield point was found in this vanadium, and the fracture was never predominately inter-crystalline despite the presence of V_2C as a noncontinuous grain - boundary precipitate. Throughout the paper, comparisons are made between the behavior of this material and other body-centered cubic structures.

W. C. WINEGARD

"Cold Worked" Austenite

Digest of "Effect of Deformation Prior to Transformation on Mechanical Properties of 4340 Steel", by Eric B. Kula and Joseph M. Dhosi, Preprint No. 129, 1959.

IN THE LAST FEW YEARS several papers have dealt with martensite formed from austenite that has been "cold worked", or deformed below its recrystallization temperature. The objective of the deformation is improvement of mechanical properties, notably strength, ductility and notch toughness. The present paper comprises a study of the effect of cold working the austenite of A.I.S.I. 4340 steel at 1550 or 1000° F. before quenching to martensite. Although the phenomenal increase in strength and ductility of steel reported by Lips and van Zuilen (*Metal Progress*, August 1944, p. 103) could not be confirmed, substantial improvements in both strength and notch toughness were achieved.

The present work employed a commercial air-melted heat of 4340 steel made in a basic-electric furnace and forged and rolled to plate 1 in. thick. Plate specimens were austenitized for 30 min. at 1550° F., rolled at 1550 or 1000° F. to the desired thickness in one pass, and oil quenched. Total time for the oper-

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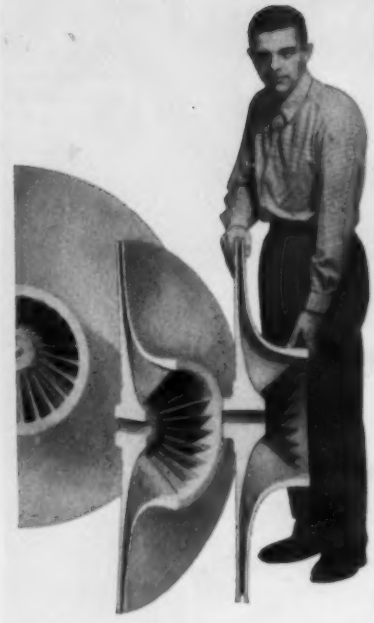

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Austenite . . .

ation at 1550° F. was 10 sec. For the 1000° F. rolling, the plates were air cooled to 1000° F., equalized for 2 min. in a muffle furnace at this temperature, rolled and oil quenched. Unfortunately, some pro-eutectoid ferrite formed during the air cooling, and this may have had some adverse effects on the results, especially on the notch-impact data. Conventional tensile and Charpy V-notch tests were made on the rolled plates after holding for 1 hr. at the appropriate tempering temperature and oil quenching.

A large volume of data is provided in the paper. A few of the high points are summarized in the next two paragraphs.

The effects on the 4340 steel of up to 72% rolling at 1550° F. and oil quenching are as follows: (*a*) There is no significant effect on the ultimate tensile strength; (*b*) the 0.2% yield strength is increased about 25% in the as-quenched condition, specifically from 205,000 to 255,000 psi. — after tempering, the improvement is smaller in magnitude, specifically from 230,000 to 255,000 psi. after a 400° F. temper; (*c*) the notch-impact properties were improved as shown by a decrease in the transition temperature, an increase in the energy level both below and above the transition temperature, and by a smaller 500° F. embrittlement on tempering.

Lowering the temperature of deformation to 1000° F., and thereby increasing the severity of the cold work, increases the absolute values of strength over those attained by deformation at 1550° F. The effects of rolling up to 72% are: (*a*) The ultimate tensile strength is improved in both the as-quench condition and after tempering — for example, after tempering at 425° F., it is raised 13%, specifically from 270,000 to 310,000 psi.; (*b*) the 0.2% yield strength is improved in both the as-quenched and tempered conditions, specifically a 19% increase from 235,000 to 280,000 psi. was noted after tempering at 425° F.; (*c*) the notch-impact properties, on the average, show no significant improvement because of the rolling.

It is interesting to speculate on the reason or reasons for the marked improvement in mechanical properties

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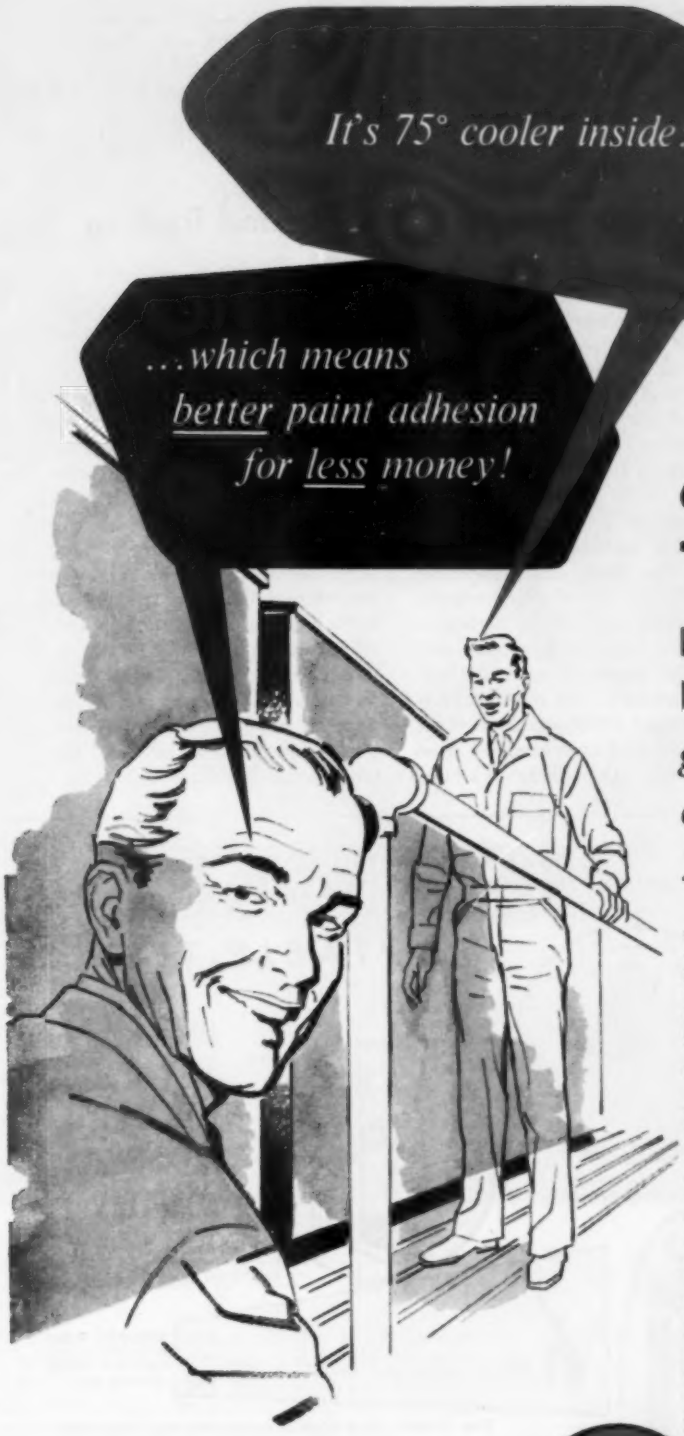

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Austenite . . .

because of cold working the austenite. One possible reason is that the martensite plates that form in the deformed austenite are finer than those forming in undeformed austenite. Metallographic evidence of this difference was found in the 4340 steel. Presumably the smaller martensite grains or platelets increase the strength and notch toughness in much the same way that small grains, in general, increase the strength and toughness of metals. Also it is possible that the well-known strengthening effect of cold working is passed along from the cold worked austenite to the martensite.

To take advantage of the cold working of austenite, we must remember that even after tempering up to 600 or 700° F. the hardness will be Rockwell C-50 or higher in steels containing 0.40% or more carbon. This precludes most machining operations. The cold working could be used where simple sections are needed, such as strip, sheet, wire or extrusions. Quenching on a continuous basis directly as the material leaves the mill or die is practical. It could also be used for small forgings where pieces could be quenched directly upon leaving the die.

O. O. MILLER

Internal Damping

Digest of "Influence of Static Stress and Temperature on Internal Damping", by J. W. Clark and W. C. Hagel, ⓢ Preprint No. 118, 1959.

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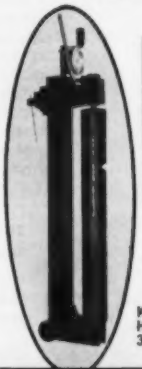

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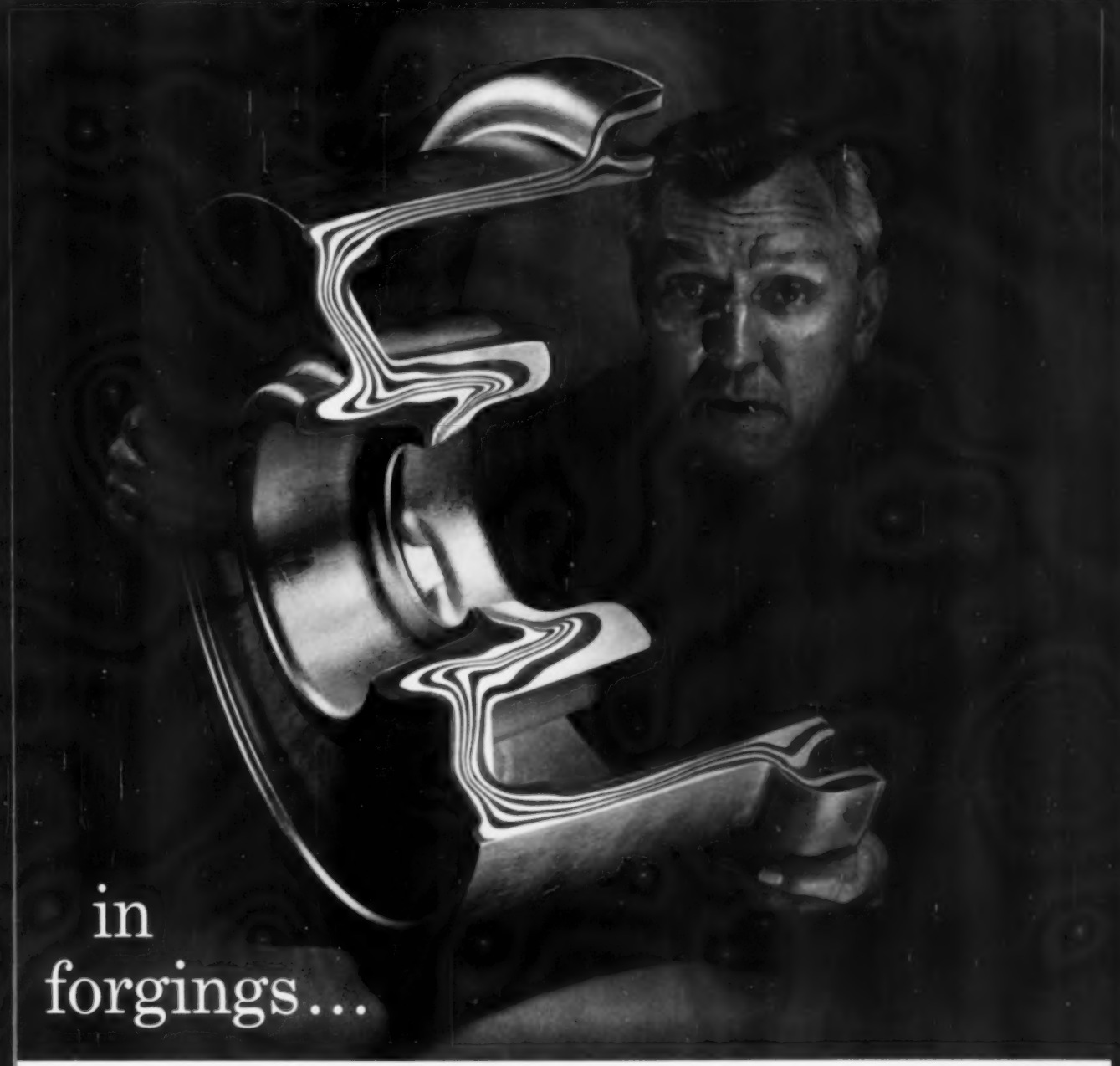

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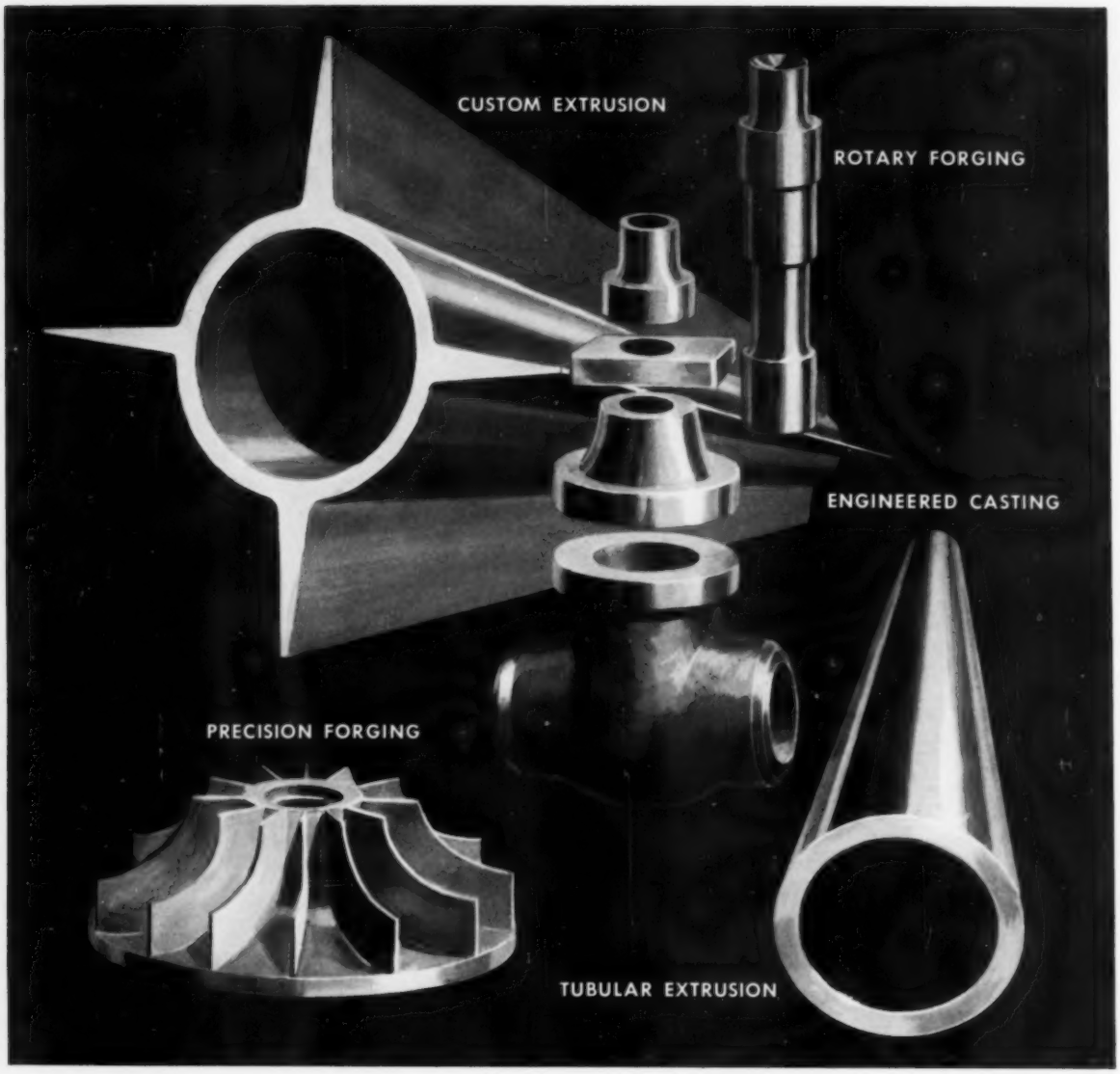

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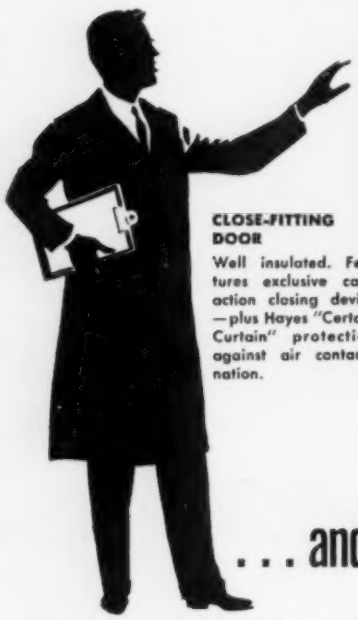

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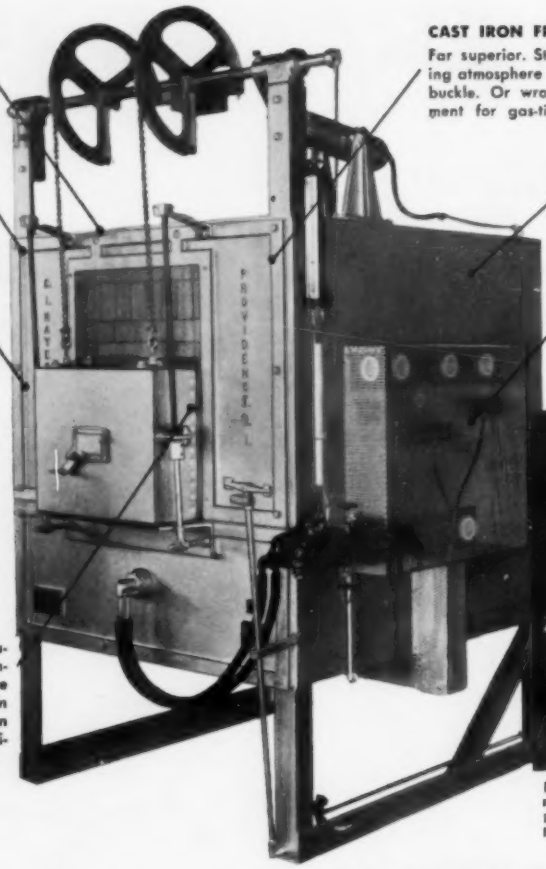

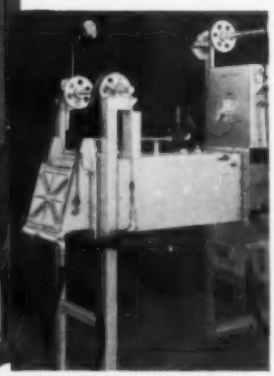

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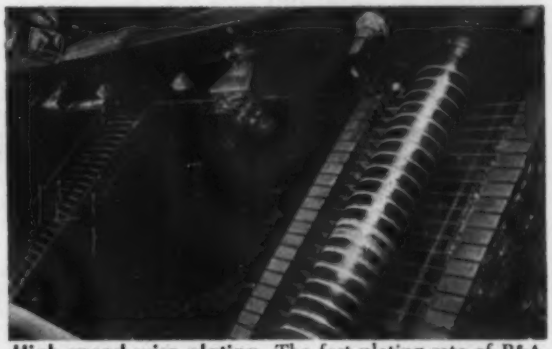

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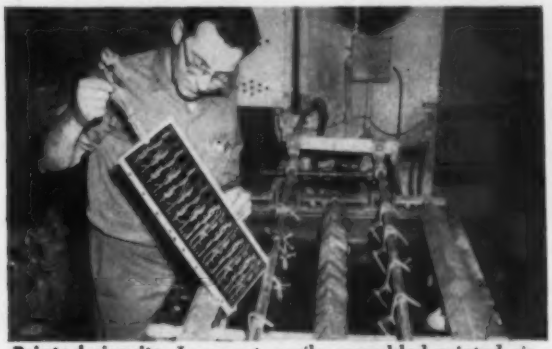

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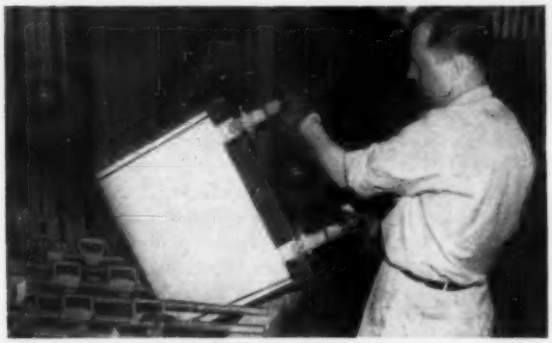

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Internal Damping . . .

This paper describes experiments on a hardenable 12% Cr stainless steel (A.I.S.I. 403), titanium, and two ferromagnetic austenitic alloys (cobalt bases, one with 24% Ni and the other with 34% Ni, 2.5% Fe) using fixed-beam specimens. For the zero static stress condition, the specimen (20 × 0.3 × 0.125 in.) was fixed horizontally at both ends to large steel blocks; one of these blocks could be rotated downward and loaded to apply a static stress. The specimen was vibrated with an electromagnetic drive coil, and the vibration amplitude was measured optically. Observation of the vibration decay which occurred when the drive coil was disconnected was made on a decibel-level recorder via a capacitance pick-up. In this way, the internal damping, expressed as the logarithmic decrement of the vibration decay curve, was measured at vibratory stresses from zero to 35,000 psi. and at static tension stresses from zero to 19,000 psi. A tubular heating furnace with a helium atmosphere permitted a range of 75 to 1100° F. to be investigated.

The data are presented as a series of curves relating the logarithmic decrement and maximum normal stress as functions of temperature and amount of static stress. In addition, changes in the internal damping due to a cyclic magnetic field were measured for the A.I.S.I. 403 alloy; similar measurements were made for the Co-Ni-Fe alloy using a d-c. field. Reference should be made to the original paper for a detailed account of the changes in internal damping brought about by these variables. The following are the main conclusions for each alloy investigated.

A.I.S.I. 403

1. At low vibrational stress (less than about 5000 psi. peak), increasing temperature results in increased internal damping.

2. At high vibrational stress (greater than about 17,000 psi. peak), the internal damping first decreases with the temperature and then increases. This minimum can yield low values of the logarithmic decrement for certain combinations of static stress and temperature. (As an example, at a high vibrational stress and under a static stress of 19,000 psi., the value of the logarithmic decrement at 500° F. is only 0.0018 compared with 0.025 at room temperature with zero static stress.) The subsequent increase in internal damping at high temperatures is attributed to the onset of microscopic plastic flow.

3. With an increasing cyclic magnetic field, damping first increases and then continuously decreases. (To give an instance, at high vibrational stress the logarithmic decrement for a field strength of 450 oersteds is 0.006 compared with 0.028 for zero field.)

Titanium

1. The internal damping of titanium is very low (logarithmic decrement of the order of 0.0005) under all the ambient conditions used.

Ferromagnetic Austenitic Alloys

1. The internal damping of these alloys falls with increasing tempera-

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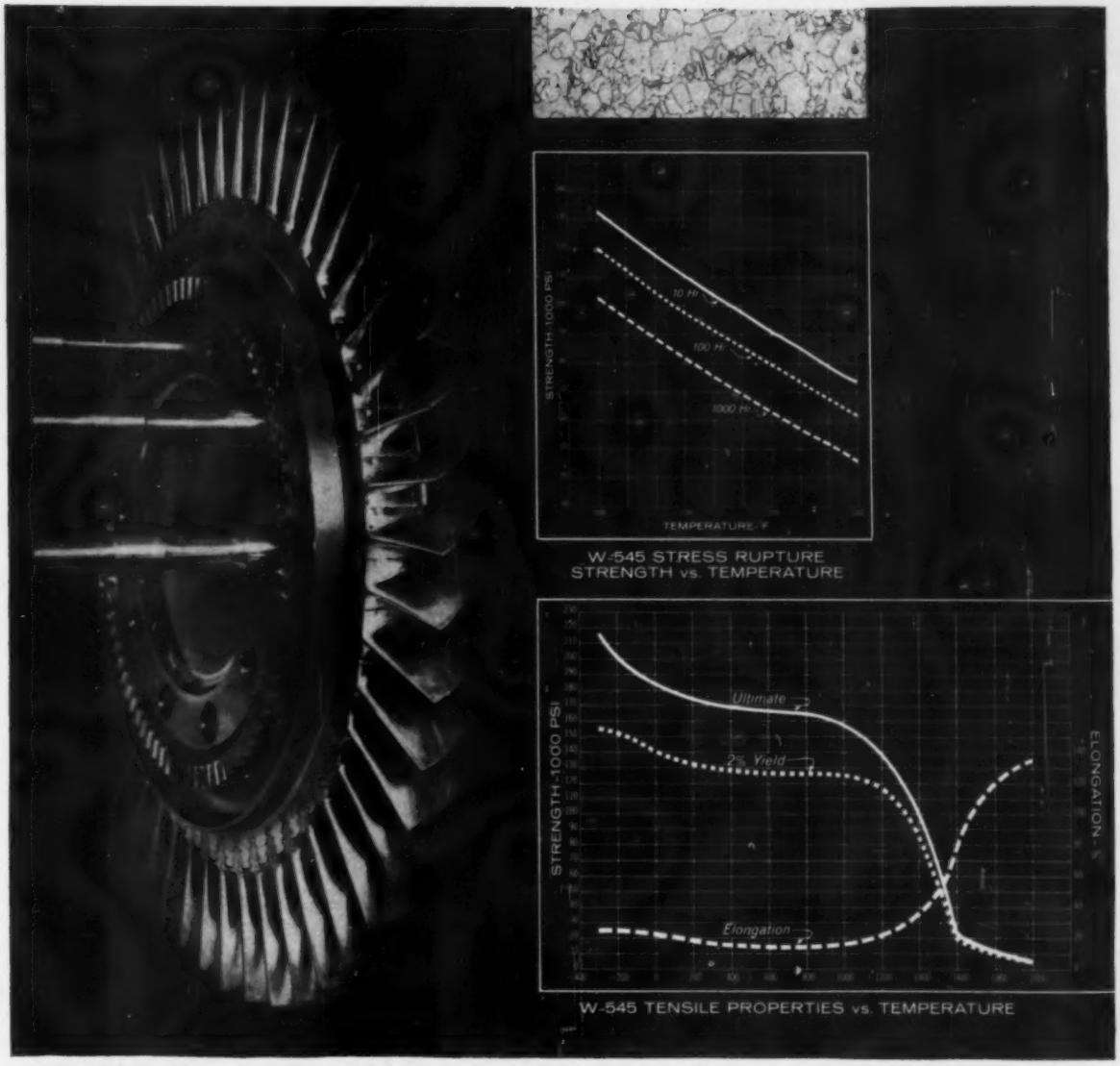

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Internal Damping . . .

ture; the dependence on temperature is, however, smaller than it is for A.I.S.I. 403.

2. Static stress or an axial d-c. magnetic field is more important in reducing internal damping than temperature.

3. At low vibratory stresses, the damping capacity of the Co-Ni-Fe alloys exceeds that of A.I.S.I. 403. At high vibratory stresses, A.I.S.I. 403 stainless steel is found to be superior.

The paper includes measurements of the dynamic elastic modulus of each material and its variation with temperature. Increasing the temperature from 75 to 1100° F. reduces the modulus by 15% for Co-Ni and Co-Ni-Fe and by 19% for A.I.S.I. 403. It was found that a reduction of 12% occurred for titanium over the temperature interval 75 to 520° F.

W. M. Williams

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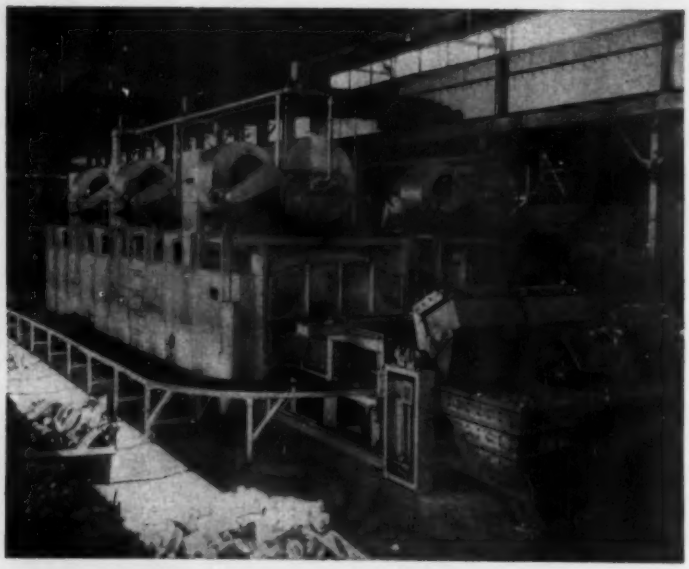

An installation of Pacific pusher type draw furnaces. Temperature range 1000-1400°F. Work is carried in boxes on roller rails, utilizing hydraulic pushers, automatic dump and box discharge. Recirculated air heating system uses metallic ducts for distributing heated air uniformly in large volume for rapid heating and best temperature uniformity.

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Slip Casting References

(*Continued from p.* 102)

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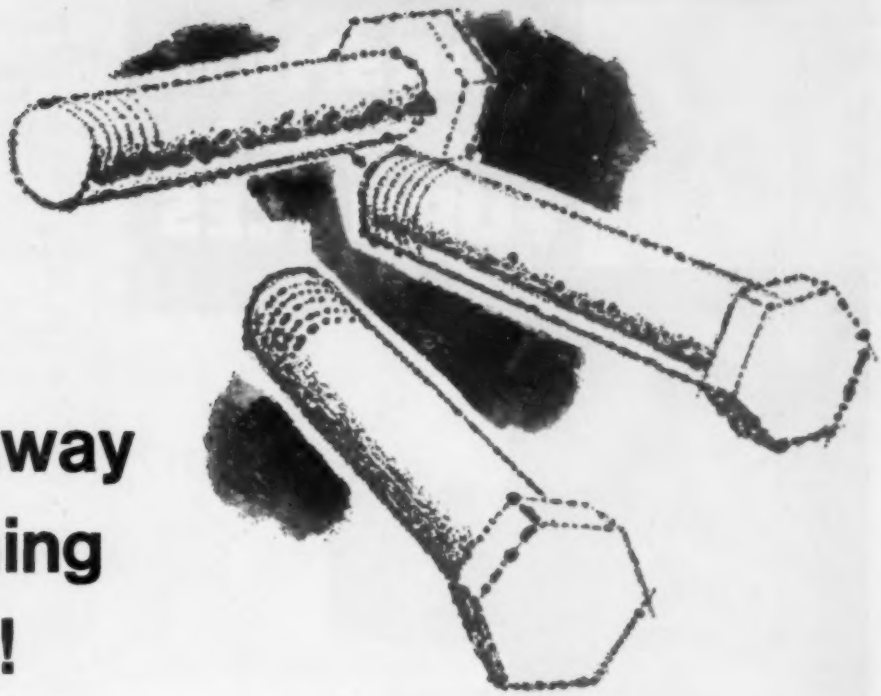
Carbon and Nitrogen in Austenitic Steels

Digest of "Effect of Interstitial Carbon Plus Nitrogen and Precipitation Reactions on the Properties of Authentic Cr-Mn-C-N Steels", by C. M. Hsiao and E. J. Dulis, Preprint No. 128, 1959.

The 24 Cr-Mn-C-N steels examined in this investigation become supersaturated solid solutions when quenched from above 2100° F. to room temperature. However, artificial aging treatments or service at elevated temperatures bring about two kinds of precipitation: (*a*) discontinuous precipitation, in which "lamellar nodules" of $Cr_{23}C_6$ or Cr_2N form at grain boundaries, and (*b*) general precipitation of $Cr_{23}C_6$ in the form of a Widmanstätten structure. The occurrence of $Cr_{23}C_6$ as grain-boundary nodules or as a dispersed precipitate depends on the



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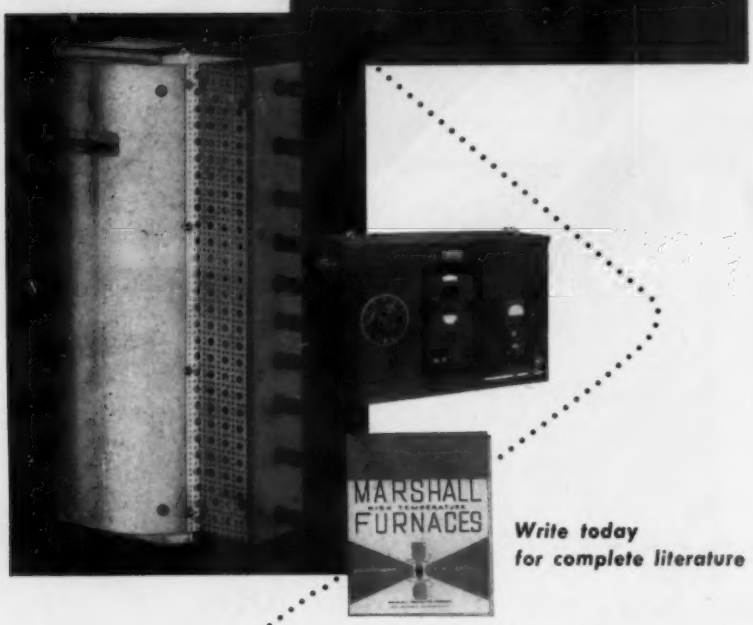

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Austenitic Steels . . .

composition of the steel, the aging temperature and whether or not an applied stress is present. The present work is concerned with the effect of these precipitation reactions on the strength and creep rupture properties and also with the effect of chromium, manganese, carbon and nitrogen on the yield strength.

Experimental ingots ranging in composition from 0.09 to 0.79% C, 0.09 to 0.84% N, 10 to 28% Mn and 12 to 25% Cr were forged to ¾-in. square bars, solution-treated for 1 hr. at 2150° F., and water quenched. Those samples which were subsequently aged were heated in the range 1200 to 1600° F., and water quenched. Tensile tests were carried out at both room and elevated temperatures; creep rupture tests were made in the range 1100 to 1800° F. Structural changes were followed by hardness, X-ray, magnetic and microscopic measurements.

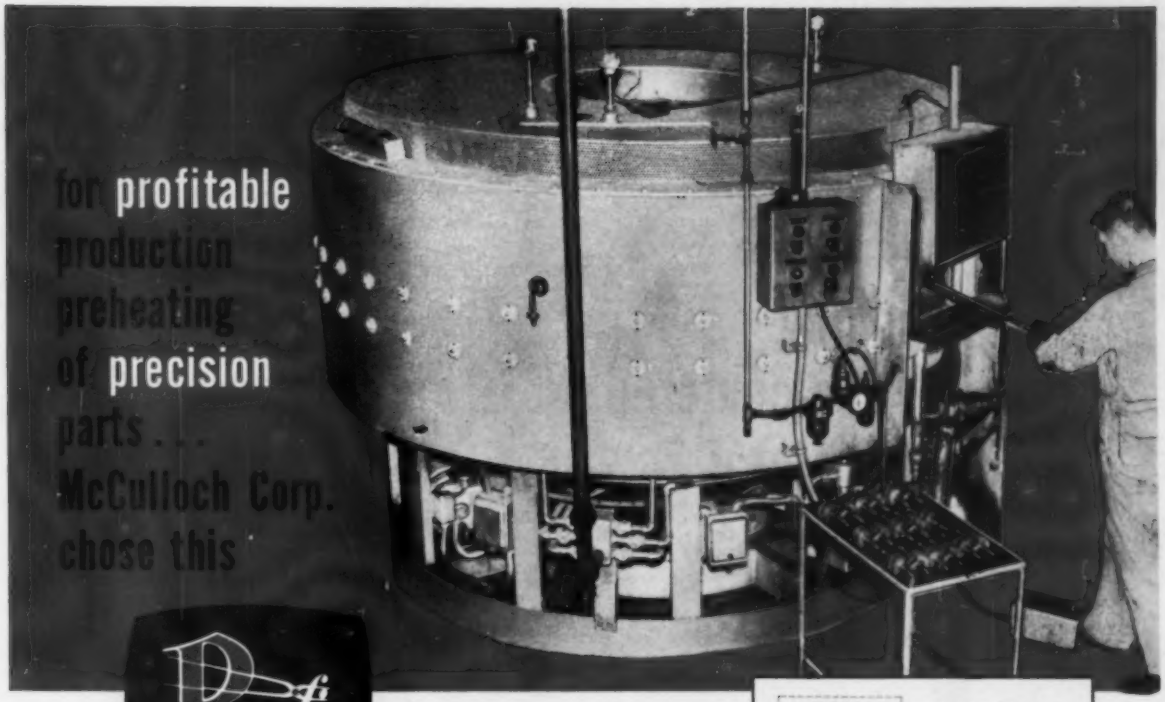
Room-temperature tensile tests on the solution-treated steels show that carbon and nitrogen had a pronounced effect in enhancing the yield strength, and, further, that this strengthening could be expressed as:

$$\text{yield strength} \propto [\text{wt.\% C} + 1.2\ \text{wt.\% N}]$$

These elements were much more important in this respect than either chromium or manganese. The authors attribute the strengthening effect to the lattice strain caused by the interstitially dissolved carbon and nitrogen. This was confirmed by measuring the lattice parameters of several of the steels. When lattice parameter was plotted against the factor (wt.% C+1.2 wt.% N), a straight line resulted, suggesting that yield strength is directly related to the enforced expansion of the lattice by carbon plus nitrogen. The rather stronger effect of nitrogen compared with carbon was put down to its greater valence electron content (five) compared with carbon (four).

Tensile tests at 1300 and 1600° F. showed that yield strength was still proportional to the factor (wt.% C + 1.2 wt.% N); variation was more pronounced at room temperature.

Precipitation, whether general or discontinuous, exerts two opposing effects. Softening can occur, due to the depletion of the matrix of carbon and nitrogen. Hardening can



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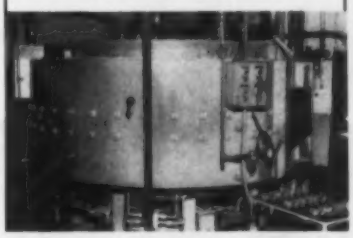

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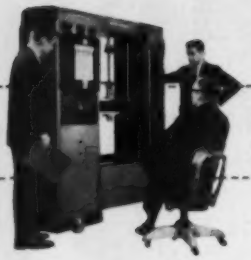

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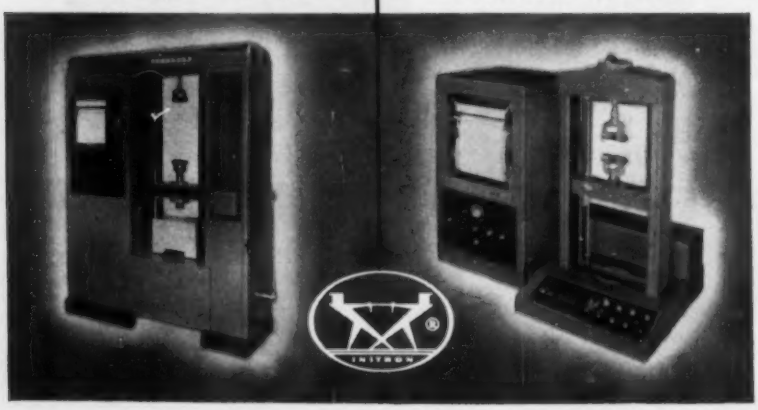

Austenitic Steels . . .

occur, because the precipitates are themselves hard and cause local lattice strains. In the present alloys, a resultant hardening always occurred after aging treatments at 1200 to 1600° F. Hardness changes were not, however, a reliable guide to changes in strength but the following conclusions could be drawn:

1. Specimens containing lamellar precipitates were weaker than when they were in the solution-treated condition. General precipitation had a strengthening effect.

2. All aged specimens failed intergranularly and had a lower ductility than their solution-treated counterparts. For example, aging a 0.4 C, 16 Mn, 17 Cr, 0.3 N steel at 1600° F. reduced the elongation from 64 to 17%.

Tensile tests carried out at 1200° F. on specimens which had been previously aged to produce different kinds of precipitate showed little variation in the yield strength. This was attributed to counterbalancing effects of softening and hardening.

A large number of creep tests were made in the range 1100 to 1800° F. to determine the effects of composition and precipitation. Tests were made on specimens that had been given a prior aging treatment as well as on specimens that had only been solution-treated (and were therefore bound to precipitate surplus solute during the test runs). The results for all the steels at all temperatures and stresses were plotted as master rupture curves.

As with the short-time yield strength values, the creep rupture strengths increased markedly with carbon-plus-nitrogen content, optimum ratio of carbon to nitrogen being about 1 to 1. The substitutional elements, chromium and manganese, were of secondary importance.

The kind of microstructure which developed during the test period, or which had been deliberately produced by a prior aging treatment, was also important in determining the creep-rupture strength. Grain-boundary (lamellar) precipitates were preferred sites for crack formation, and were therefore detrimental to creep strength. Finely dispersed precipitates were found beneficial to the creep and creep rupture properties. W. M. MILLER

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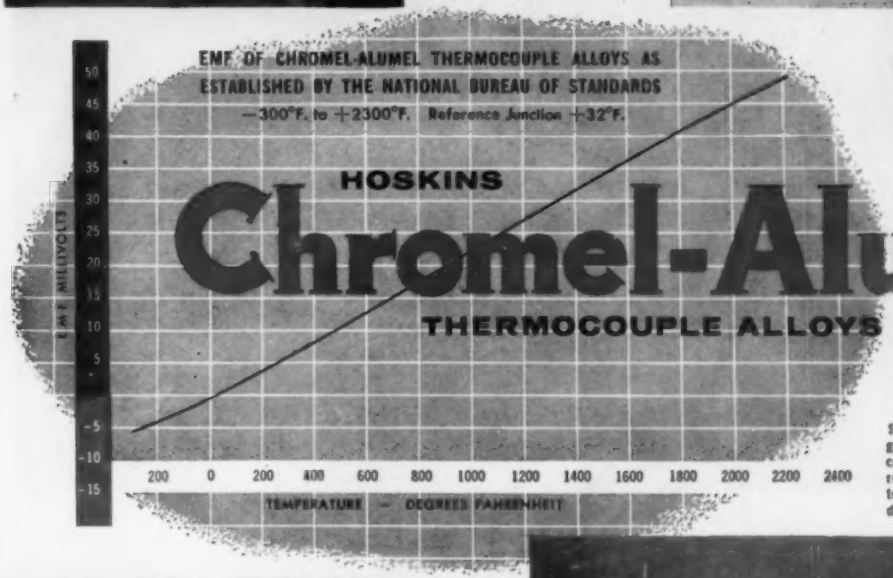

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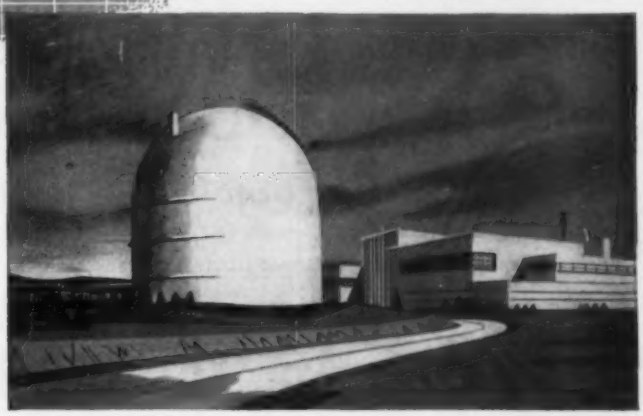

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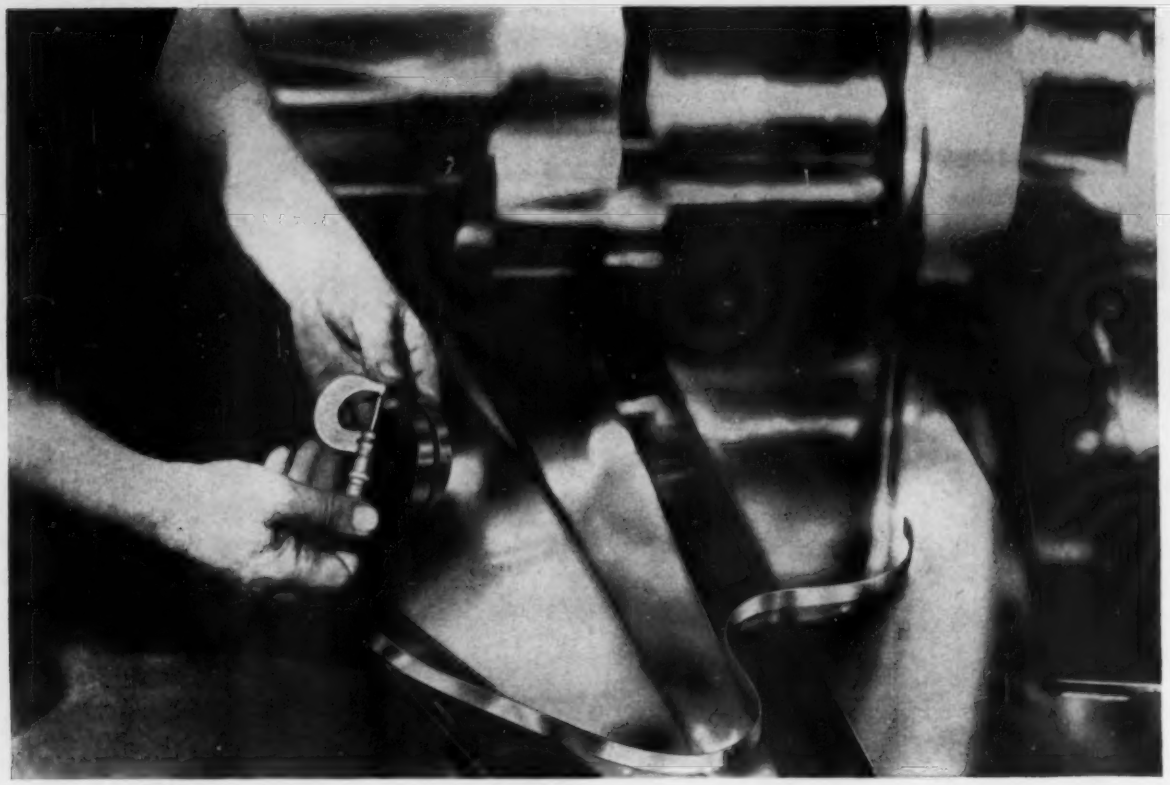

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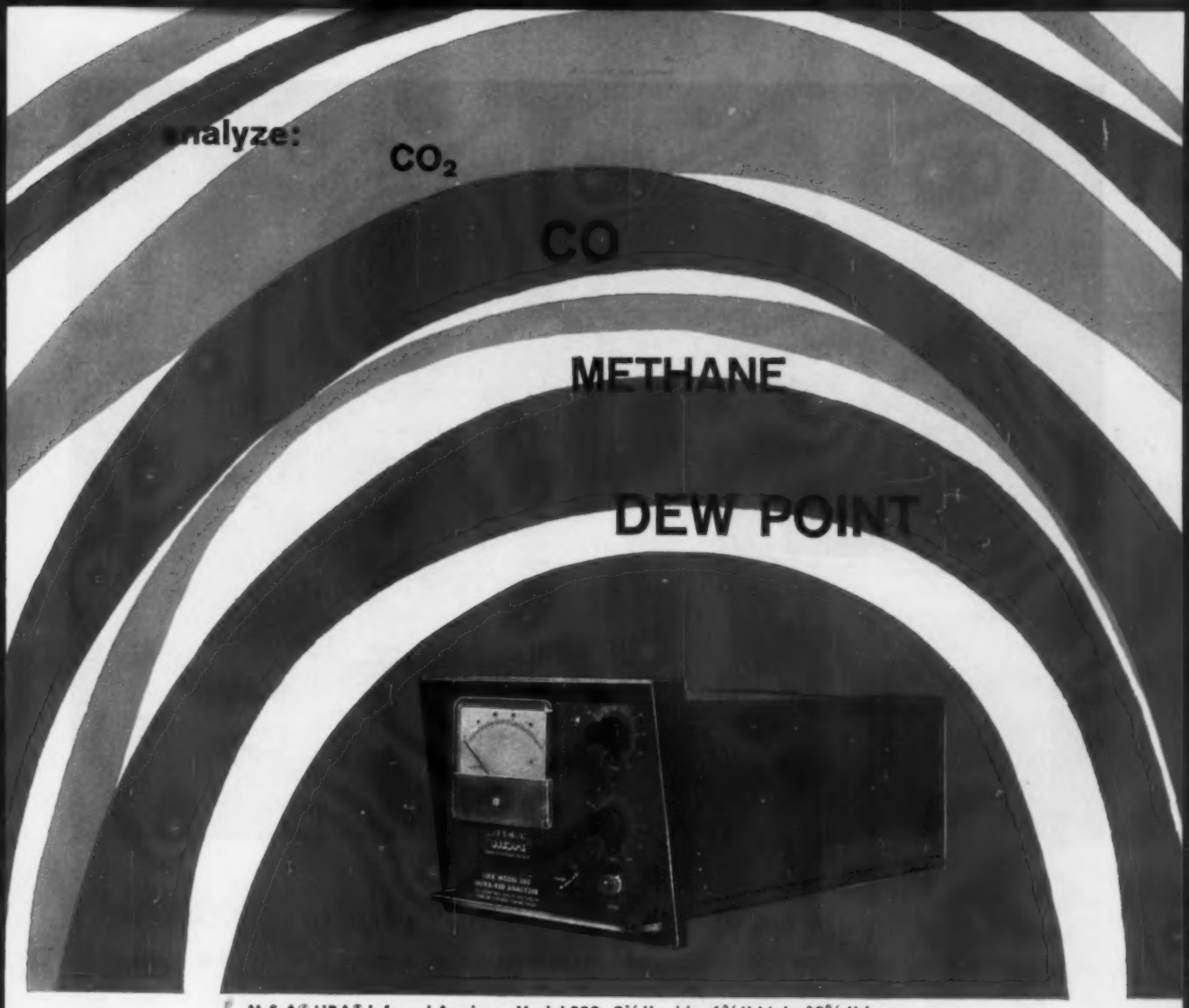

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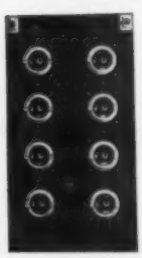

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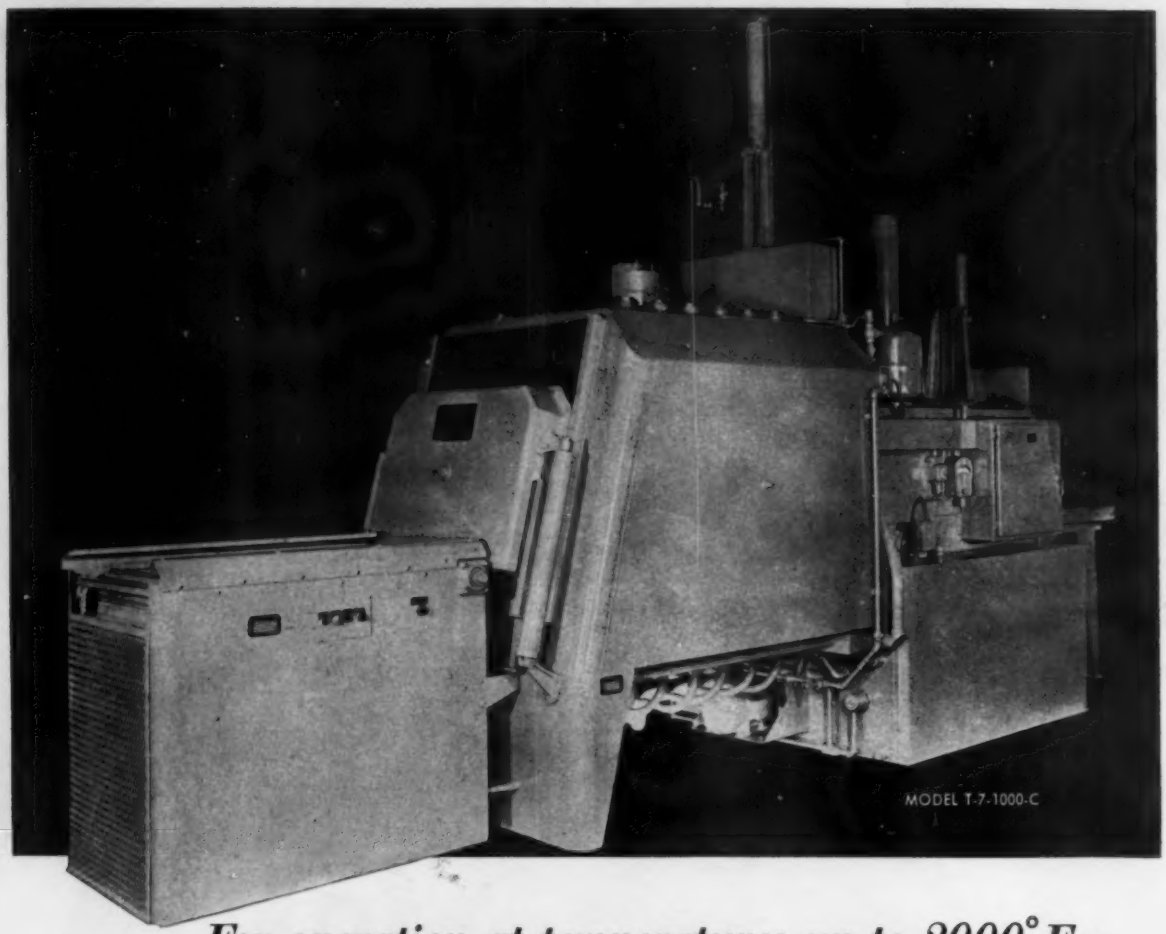

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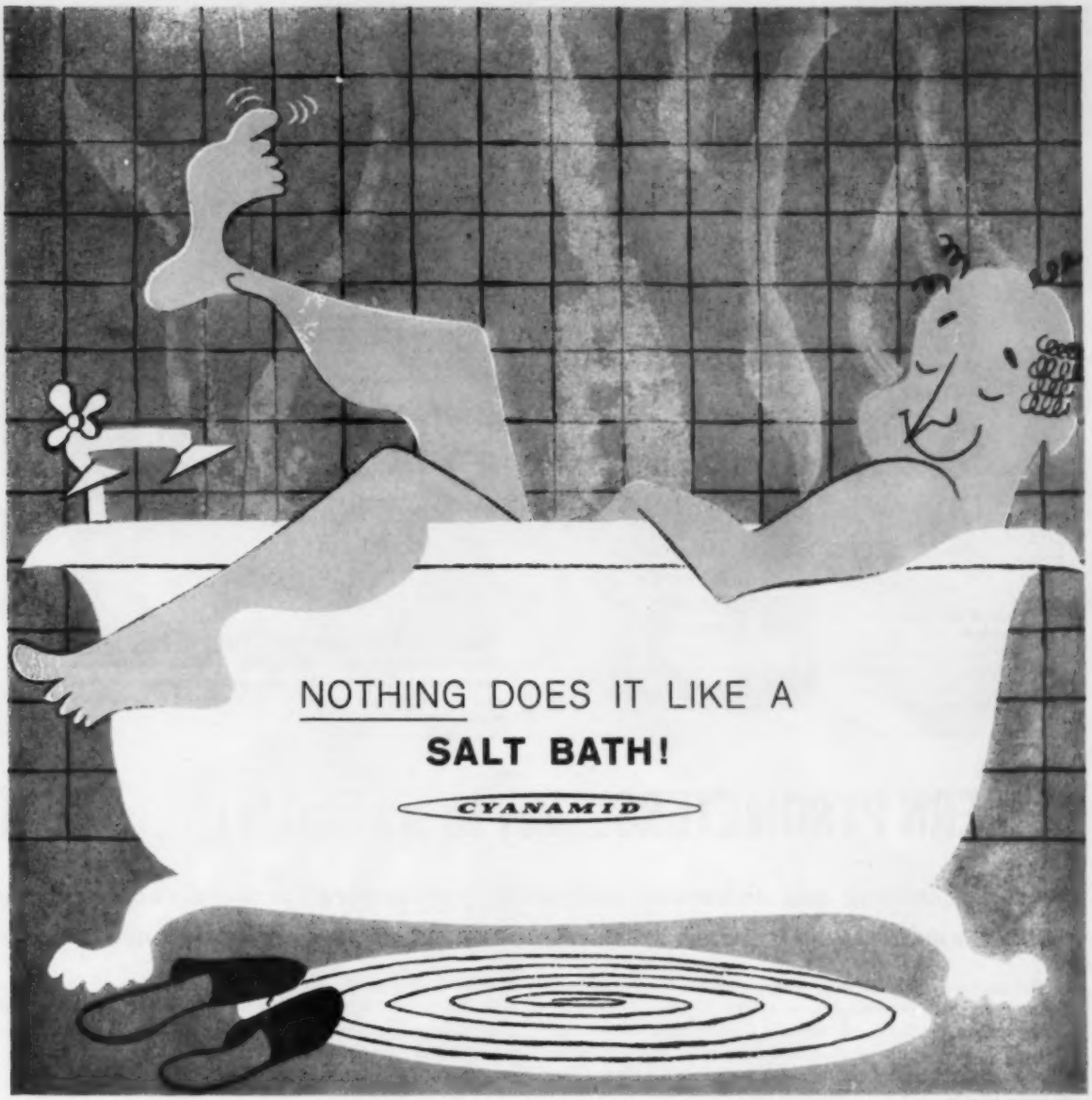


There are other ways to heat treat metals, but nothing quite compares in *deep-down, over-all, satisfying* results with a Salt Bath.

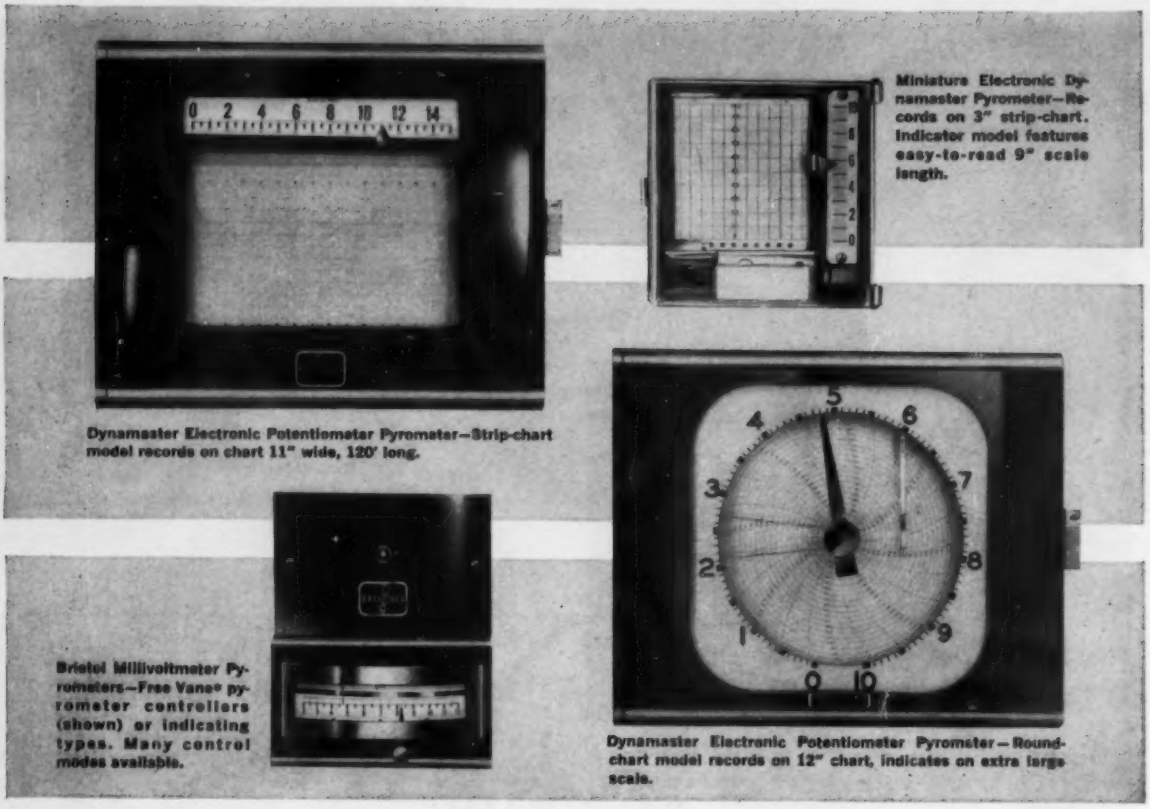
For one thing, salt furnaces heat work faster and more evenly because temperatures are uniform throughout the bath. Too, salt baths *eliminate* scaling and decarburization without the use of special atmospheres . . . even from bath to quench since a thin protective layer covers the metal. Partial immersion of the work also allows selective heating.

With all of this, initial *costs,* operating costs and maintenance costs are low. Long pot life means less down time; high thermal efficiency means low operating expense. Mechanization saves labor costs, increases production.

Why not check with your *Process Chemicals* salesman and learn of the "engineered advantages" of Cyanamid's highest quality heat treating salts—or drop us a line. Then, put your heat treating, case hardening and carburization jobs into a bath filled with Cyanamid Salts, settle back and enjoy the satisfaction of a job well done.

AEROCARB® – Carburizing Compounds
AEROCASE® – Case Hardening Compounds
AEROHEAT® – Heat Treating Salts

CYANAMID
AMERICAN CYANAMID COMPANY
PROCESS CHEMICALS DEPARTMENT
30 Rockefeller Plaza, New York 20, New York
In Canada: Cyanamid of Canada Limited, Toronto and Montreal



Dynamaster Electronic Potentiometer Pyrometer—Strip-chart model records on chart 11" wide, 120' long.

Miniature Electronic Dynamaster Pyrometer—Records on 3" strip-chart. Indicator model features easy-to-read 9" scale length.

Bristol Millivoltmeter Pyrometers—Free Vane* pyrometer controllers (shown) or indicating types. Many control modes available.

Dynamaster Electronic Potentiometer Pyrometer—Round-chart model records on 12" chart, indicates on extra large scale.

MODERN PYROMETERS...key to profitable use of HEAT

Bristol recording and automatic controlling pyrometers for temperatures up to 5000°F can help you increase product uniformity, cut fuel and maintenance costs

Bristol makes a wide range of pyrometers for every requirement: Electronic potentiometers, millivoltmeter and radiation types . . . for furnaces, ovens . . . every type of heating equipment, every kind of fuel. The reliability and accuracy of these precision instruments have been proved in thousands of installations.

Take just one advanced Bristol instrument, for example, the Electronic Dynamaster* Potentiometer Pyrometer:

CONTINUOUS STANDARDIZATION PLUS ACCURACY OF STANDARD CELL

Continuous standardization in Dynamaster Electronic Pyrometers requires no dry-cells, **but still retains the precision standard cell for highest stability and accuracy of voltage reference.** Results: No interruption to operation, no batteries to change. And here are just a few of the Dynamaster types available:

A model for every requirement: Dynamaster Pyrometers are available as single-pen, two-pen, and multiple-record (up to 24 points) *strip-chart* instruments and as *round-chart* instruments.

Electric and pneumatic controllers: Both strip- and round-chart instruments are made in a very wide variety of controllers that meet every furnace and oven control requirement, including the following in a great many forms:

Electric Control—on-off, proportional input, 3-position, proportioning, proportional with automatic reset, and time-program.

Pneumatic Control—on-off, proportional, and proportional with reset.

Miniature Dynamaster Pyrometer: Full plug-in flexibility . . . takes only 5" x 5½" of panel space, but has same basic accuracy, same time-tested operating principle as full-size Dynamaster pyrometers described above. Ideal for graphic panels and centralized recording or indicating of large numbers of variables. Either electrical or pneumatic control types available.

Write for complete data on Bristol Pyrometers—and remember Bristol offers a complete line of thermocouples and pyrometer accessories. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn. *T.M. Reg. U.S. Pat. Off.

BRISTOL... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

FLEXAL S	Hot dip, dry film lubricant and rich, dry drawing compound.
FLEXAL MCA	Metallic stearate base. Medium varigrind compound.
FLEXAL MCF	Metallic stearate base. Rich, fine mesh drawing compound.
FLEXAL MCL	Lean, fine, dry lubricant for low carbon bright and cold heading wires.
FLEXICHEM CS	Extremely fine particle size (5-7 microns), pure metallic stearate, excellent parting agent for resin coated sand molds; lubricant for powder metallurgy parts.

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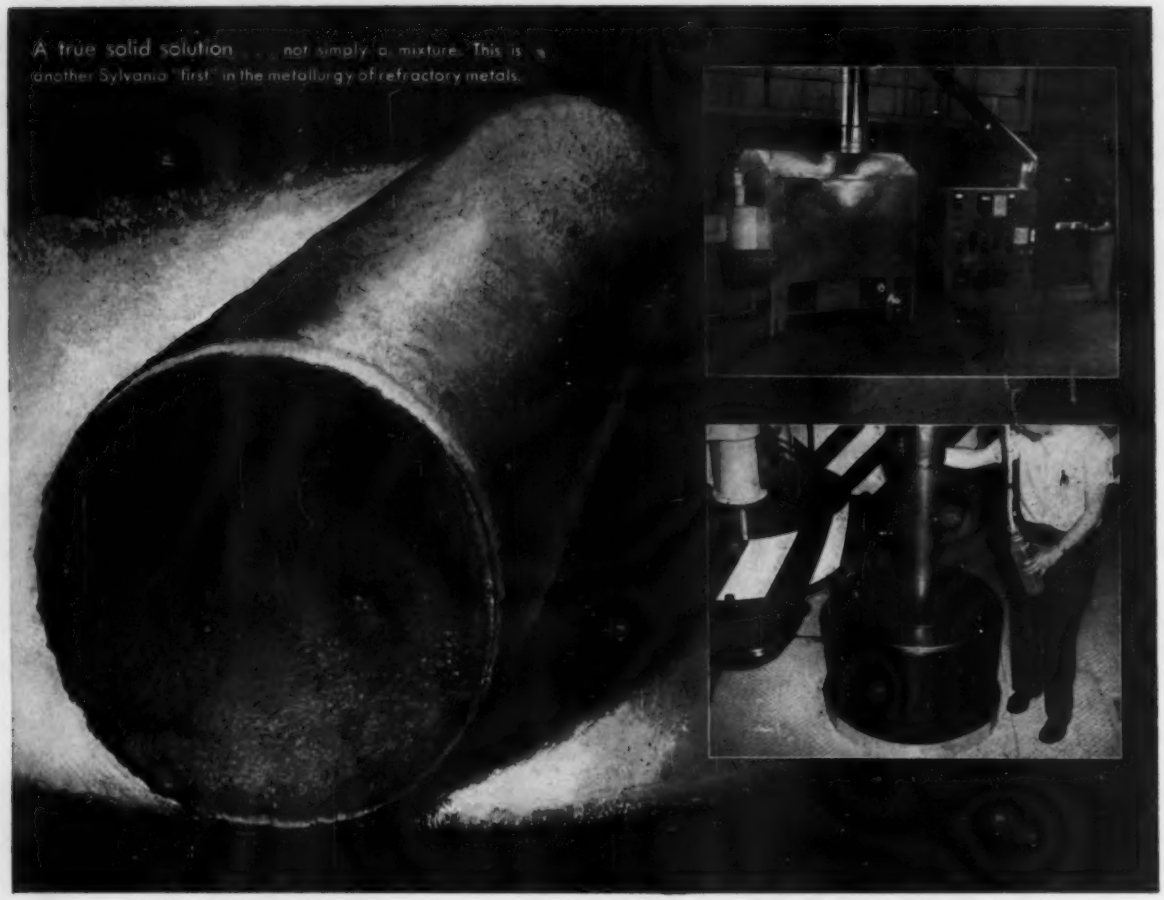

Breakthrough in 50/50 Tungsten-Molybdenum!

A TRUE SOLID SOLUTION of tungsten and molybdenum is now in production at Sylvania. Finished ingots and electrodes can be made to contain any proportions of these metals, including 50/50.

The new Sylvania process assures a true solid solution throughout every ingot . . . an assurance never possible with other processes.

This breakthrough results in a virtually new metal . . . combining many of the best qualities of both tungsten and molybdenum with hitherto unobtainable uniformity.

Sylvania currently is turning out arc-casting electrodes and direct-forging ingots in sizes up to 4 feet long and 5 inches in diameter. New equipment now being installed will yield ingots to 10 inches in diameter and 4 feet in length. Ask your Sylvania representative for further details, or write to the address below.

SYLVANIA GENERAL TELEPHONE SYSTEM

Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

SYLVANIA ELECTRIC PRODUCTS INC.
Chemical & Metallurgical Div.
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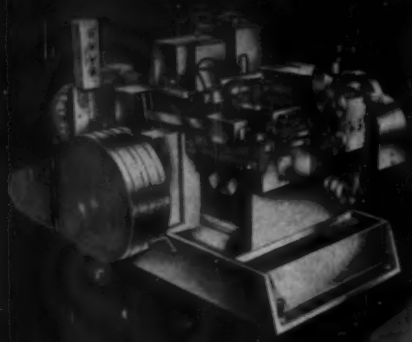

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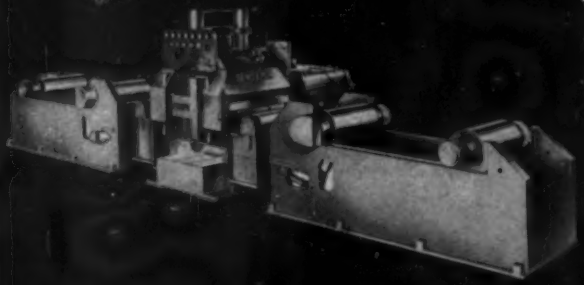

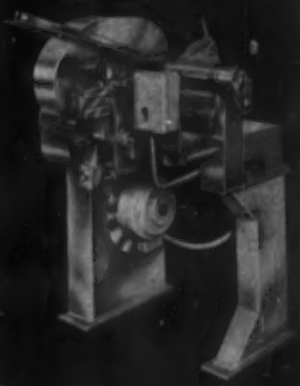

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PRESSES

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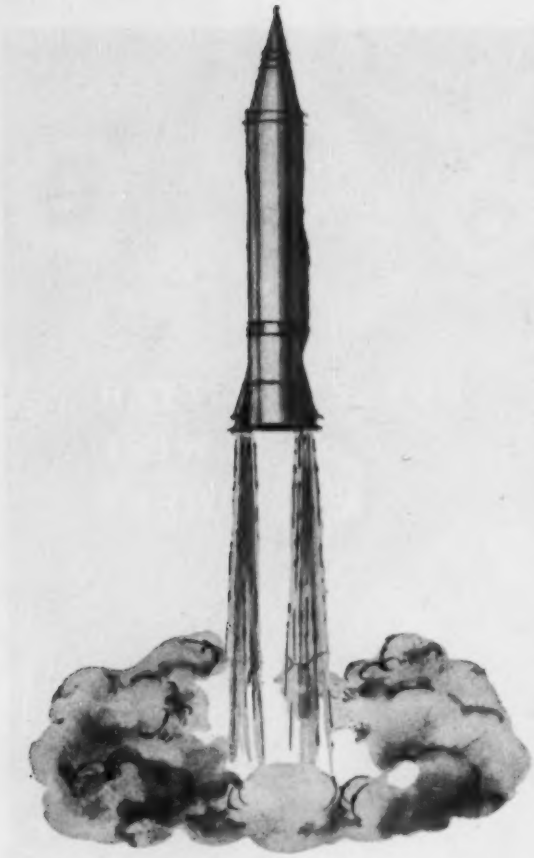
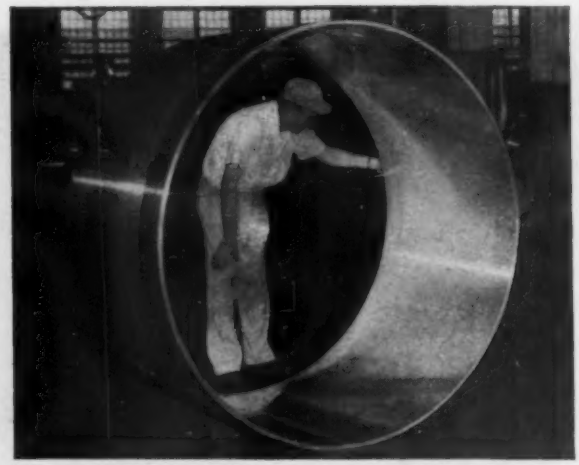




First stage motor case ring—vacuum-melted D6A steel

Second stage motor case ring—vacuum-melted 300M steel

Third stage motor case ring—air-melted AMS-256 steel

QUALITY OF "MINUTEMAN" MISSILES PARTS DETERMINED BY STANDARD STEEL WORKS RESEARCH

Months of research and development of various rigid quality-control procedures at Standard Steel Works Metallurgical Laboratories preceded the delivery of "Minuteman" missiles parts of extremely high-quality material.

Standard Steel Works' laboratory facilities—second to none in industry—make possible delivery of unusual forgings from special steel alloys in record time. Missiles parts of the highest cleanliness ratings have been furnished from both air and vacuum melted steel. All are subjected to ultrasonic inspection under water for defects and to microscopic examination for cleanliness.

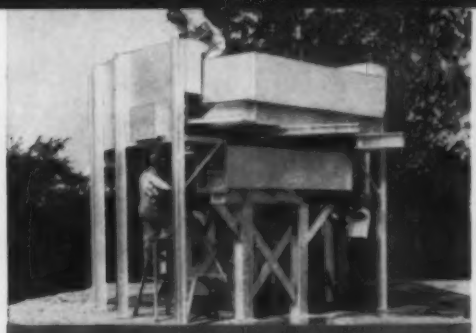
Standard Steel Works Division
BALDWIN · LIMA · HAMILTON

BURNHAM, PENNSYLVANIA

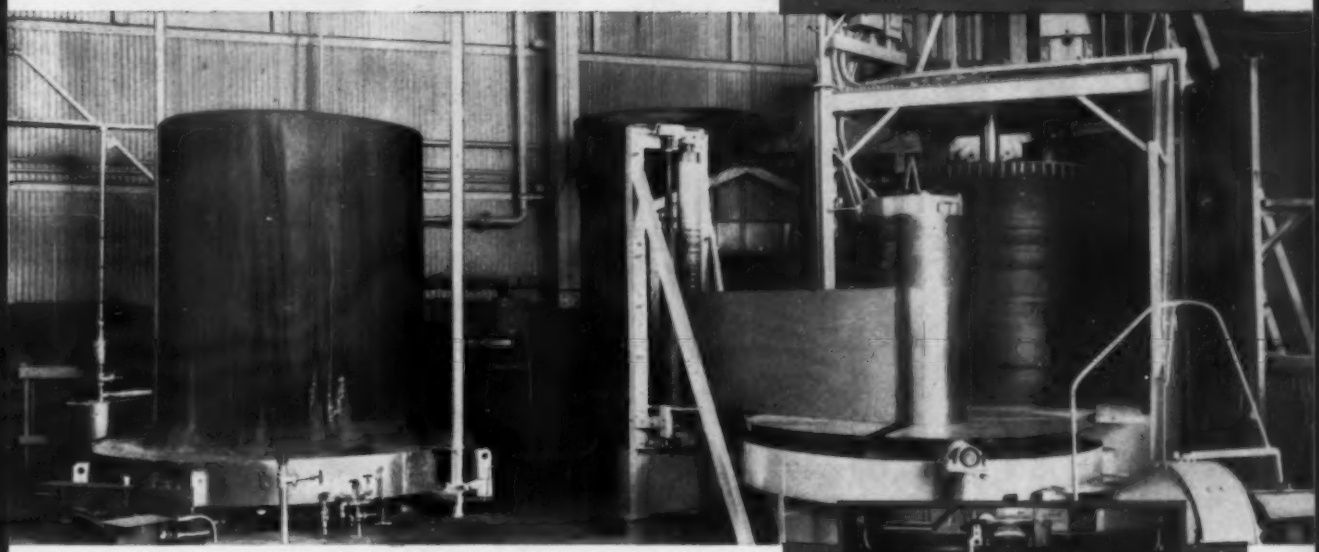
Rings • Shafts • Car wheels • Gear blanks • Flanges • Special shapes

RESEARCH IN DEPTH...

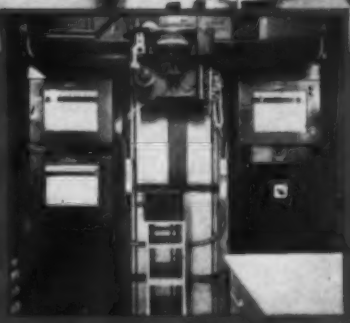
keeps Lee Wilson first in annealing



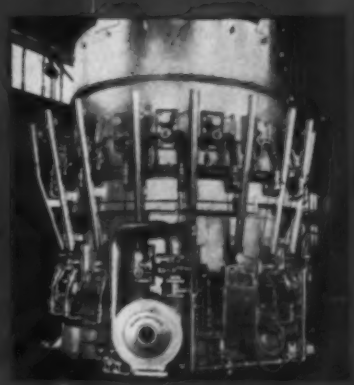
Full-scale wooden mock-up of two sections of the eight-zone new Lee Wilson Rotary Opened Coil Annealing Furnace enables Lee Wilson engineers to study design and construction details.



Typical scene at Lee Wilson Research Center shows test coil (on the right) being tight-wound for temper rolling after annealing; on the left, an inner cover over a test charge being purged.



extensive temperature and recording installation to make permanent records of every test.



Full-scale production furnace for annealing opened coils.

Research in depth keeps Lee Wilson the first name in advanced annealing techniques and equipment. Here is shown a part of the full-scale experimental equipment built by Lee Wilson engineers to thoroughly test the new *opened coil method* of annealing under actual operating conditions. Such extensive research facilities aid in the design and construction of better equipment and enable steelmakers to test their products in this new equipment. The world's leading steelmakers have sent silicon, tin plate and carbon coils to the Lee Wilson Research Center for thorough annealing tests. Full-size coils of many different analyses have been annealed in this opened coil pilot plant with exceptional results.

It is this kind of "beyond-the-drawing board" effort that is the secret behind the advanced design and dependability of Lee Wilson annealing equipment. If you want concrete evidence of what the world's most highly developed annealing techniques can do for your product, why not arrange now for a coil test.

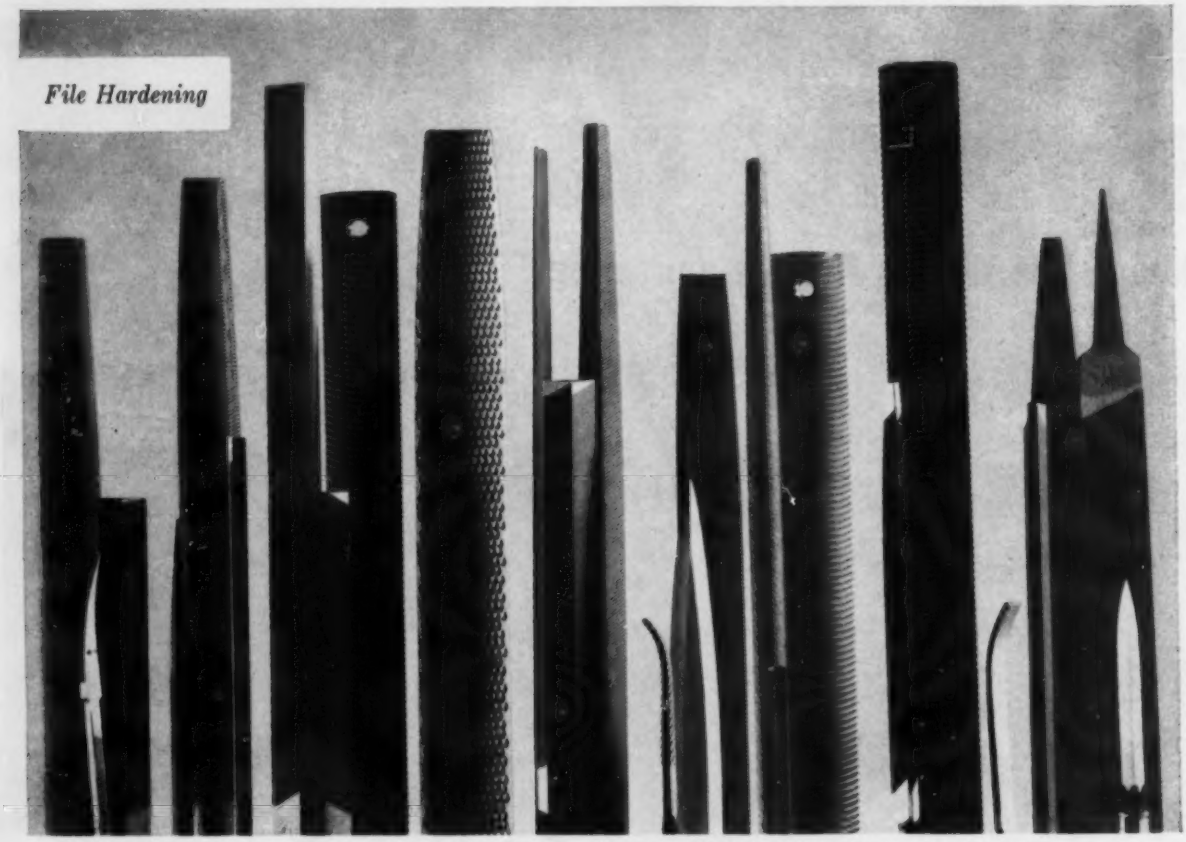
Lee Wilson* ENGINEERING COMPANY, INC.

2000S WEST LAKE ROAD • CLEVELAND 16, OHIO

HIGH PRODUCTION ANNEALING SYSTEMS

MAKE THE BEST METALS BETTER

* ORIGINATORS AND LEADING PRODUCERS OF OPENED COIL AND SINGLE STACK FURNACES



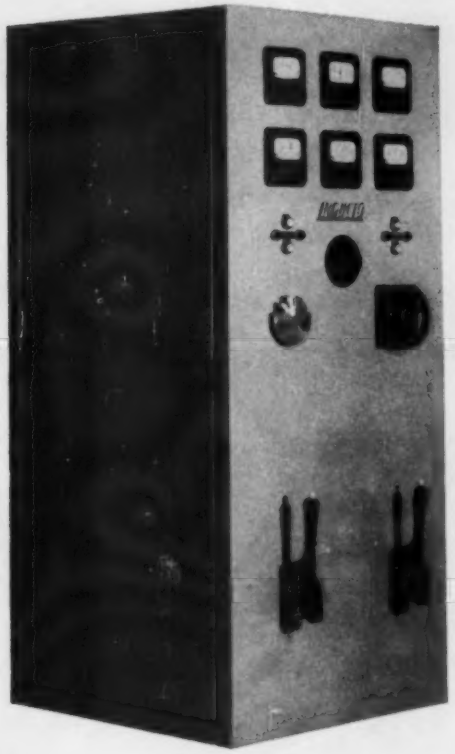
Nicholson File Co.: Many thousand files are hardened daily; Speedomax control helps keep rejects to absolute minimum.

Control of lead pot temperatures a problem?

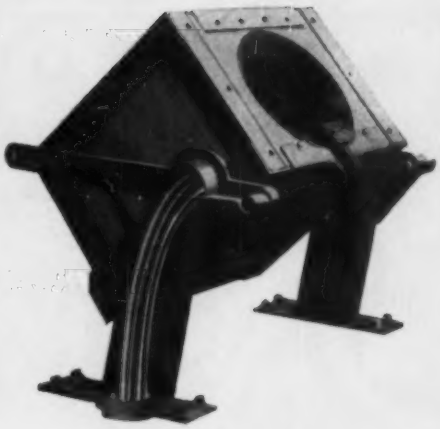
Not at Nicholson File Co., Anderson, Ind., where Speedomax® H controllers are holding critical hardening temperatures to within ±5 F. With file hardening an art, Speedomax H permits a skilled operator to devote all his attention to producing a hard, straight, undistorted file. Since installing automatic control, *rejects have been minimized . . . pot life has increased substantially . . . new-operator training time appreciably reduced.* Rugged, compact and completely reliable, Speedomax H is providing similar process benefits on numerous other heat treat operations . . . is helping both to modernize production and to produce a quality product. Whatever your heat treat, it'll pay you to investigate Speedomax H! For details, contact your nearest L&N office or write 4927 Stenton Avenue, Philadelphia 44, Pennsylvania.

With automatic control holding pot temperatures to within ±5F, skilled operators can devote all their attention to producing files which consistently meet maximum hardness and straightness specs.

LEEDS & NORTHRUP
Instruments · Automatic Controls · Furnaces



**INDUCTOMELTING is high-frequency induction melting PLUS the additional advantages of INDUCTO design features and engineering techniques.*



INDUCTOMELTING MEANS* **Savings**
IN INSTALLATION AND OPERATING COSTS

From the moment your INDUCTO equipment is installed, you start saving money. And this saving continues for the life of the equipment.

The reason is simple. Inductotherm engineers have applied the advantages of modern design to the well-established principle of high-frequency induction melting. Take INDUCTO control cabinets, for instance . . . they are surprisingly compact yet they contain all the control, metering equipment, capacitors, transformers and selector switches necessary for the efficient operation of induction furnaces. We ship them completely assembled to keep installation costs at a minimum. Now . . . look at the furnaces. The exclusive INDUCTO power leads enter through the trunnion. No furnace pits are required. There's very little bus bar to buy and install because the runs are short. Installation time is minimized—an additional saving because you are in production faster.

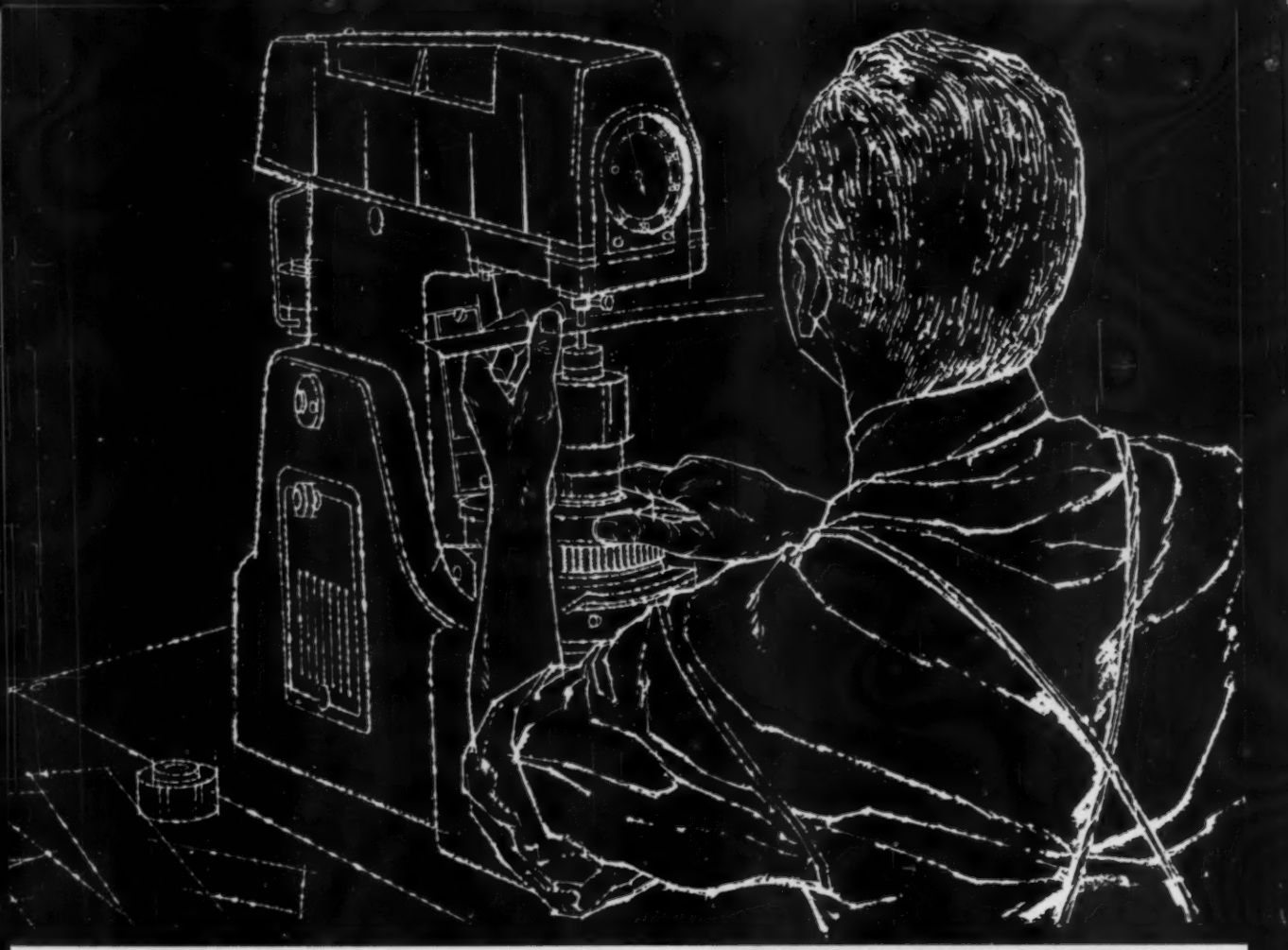
How does INDUCTO equipment operate? Your men will find that it handles easily—effectively. Its high melting speeds and precise temperature control will soon show you how INDUCTO equipment often pays for itself in two to three years of operation.

The features which cut installation costs also contribute to operational savings. For example, the water-cooled furnace leads are specially constructed to handle high-frequency currents easily. Because they enter the furnace through the trunnion, they can be much shorter, thereby reducing electrical losses. The furnace selector switches, designed by Inductotherm engineers, are the most efficient of their kind. They are located on the lower front of the panel to provide a continuous current flow from the capacitors to the furnaces and to eliminate unnecessary bus bar. The high-frequency transformers, built to INDUCTO specifications, have an efficiency rating of 99.5%. In fact, every component reflects our successful efforts to achieve top operating efficiency. It all means better melting—INDUCTOMELTING!

These cost-saving features are detailed in our Bulletin 70 . . . send for your copy today. INDUCTOTHERM CORPORATION, 412 Illinois Ave., Delanco, N. J.

INDUCTOTHERM

. . . the mark of modern melting



PRECISE HARDNESS CONTROL

to your specifications with

J&L Cold Rolled Strip Steels

Variations within standard commercial limits of hardness for strip steels may not provide the quality needed for most critical applications.

At J&L the newest equipment and techniques are used to provide controlled hardness—to your specifications.

Basic oxygen converters, high standard open hearth practice and electric furnaces provide optimum melting conditions, new hot strip mills are specifically designed to produce the finishing temperatures needed for inherent quality. Cold mills, annealing and normalizing furnaces and other equipment are designed specifically for precision strip steel processing.

With an organization experienced in specialized strip steel processing, your most rigid specifications can be met consistently.

For your convenience, precision strip facilities are available to you in our plants at Youngstown, Indianapolis, Los Angeles and Kenilworth (N. J.)

The small unit rotary annealing method assures precision temperature control and develops optimum hardness and microstructure for high carbon, low carbon and alloy strip.

J&L

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TEMPERED SPRING STEEL • ZINC AND COPPER COATED

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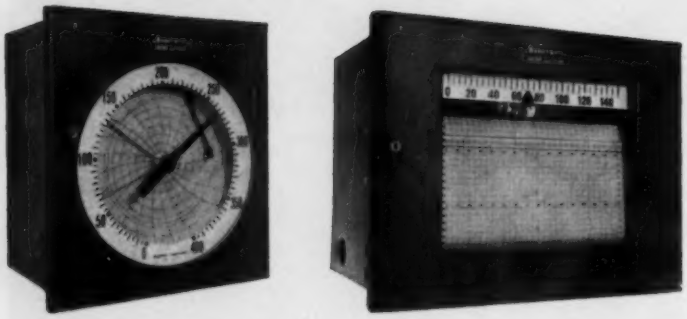
TEMPILSTIKS° are widely used as a standard method of determining temperatures in welding procedures, metal working and heat treating, steam trap maintenance, tire-retreading, plastic forming and hundreds of other heat-dependent operations. Available in 80 different temperature ratings . . . $2.00 each. Most industrial supply houses carry Tempilstiks°. If yours is an exception, then write direct to us for further information.

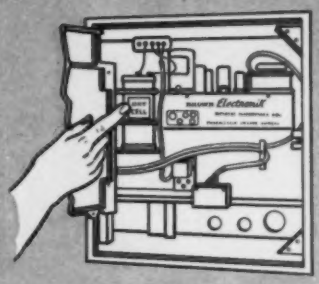
Tempil° CORPORATION • 132 West 22nd St., New York 11, N. Y.

VISIT US AT BOOTH 225—NATIONAL METAL EXPOSITION—CHICAGO—NOV. 2-6

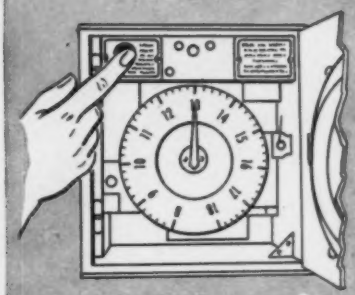
New Constant Voltage Unit makes *ElectroniK* instruments better than ever

by eliminating these problems

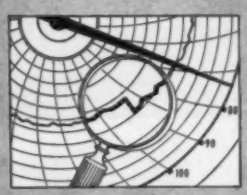




No *batteries* to replace . . . no recording or control deviation due to low battery voltage.



No *button* to push on the instrument for standardization . . . no false readings because of failure to standardize.



No *blanks or shifts* in the instrument's response to variables. You get complete continuity of recording and control.

All new Precision Line *ElectroniK* circular and strip chart instruments have the new Honeywell Constant Voltage Unit that accurately regulates d-c reference supply to the measuring circuit. No more batteries, standard cells or standardizing mechanisms . . . and no more of the problems they pose.

The Constant Voltage Unit delivers a constant, rectified voltage from line supply. It uses dependable Zener diodes and a reliable ambient temperature compensator.

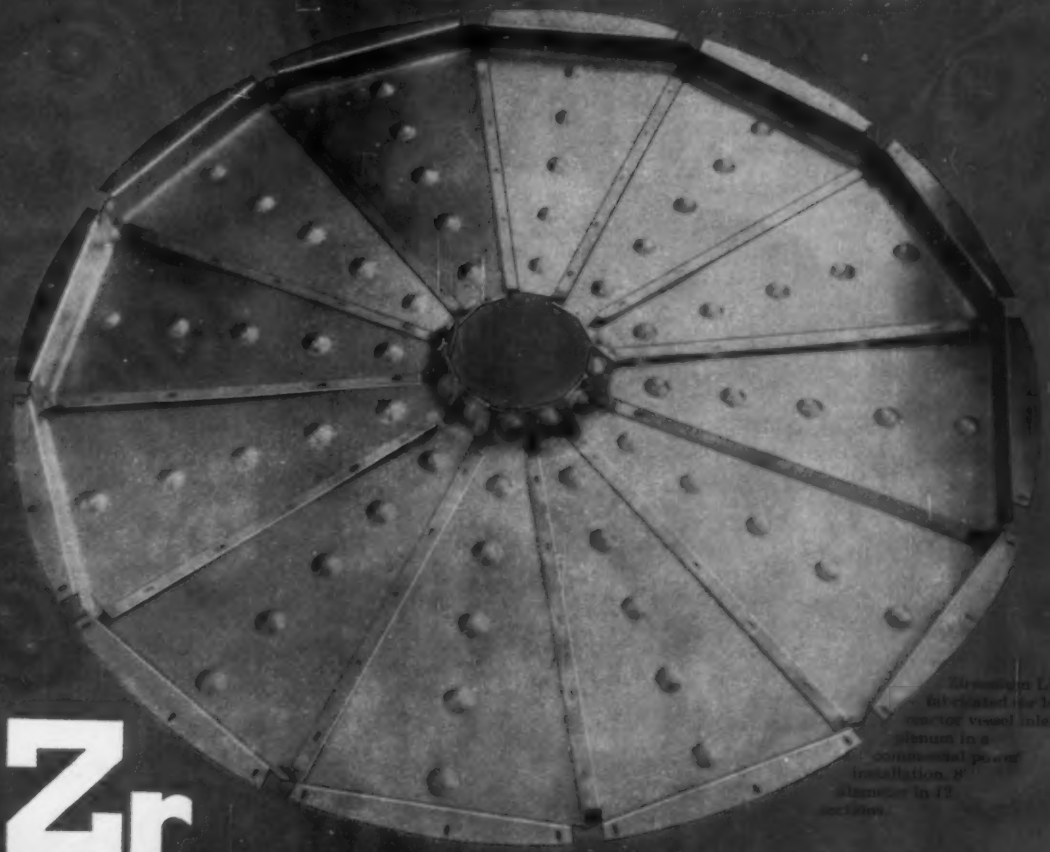
This latest improvement in *ElectroniK* instruments assures even greater dependability, and less maintenance, and is still another reason why *ElectroniK* instruments are your best value in measurement and control. Get full details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

First in Control

CATCHES MOLTEN URANIUM



Zirconium Liner fabricated for lower reactor vessel inlet plenum in a commercial power installation. 8' diameter in 17 sections.

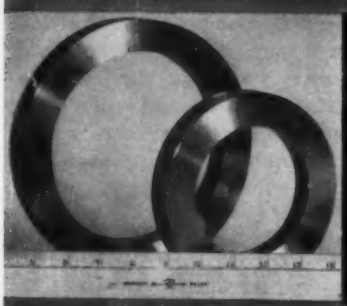
Zr

ASSEMBLIES MADE TO ORDER

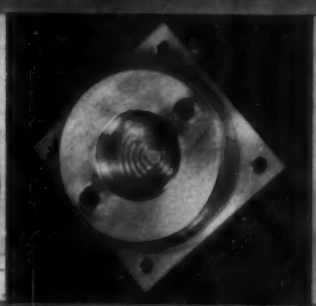
...MACHINED
...WELDED
...FINISHED

Facilities are now available for fabricating Zirconium metal assemblies to your specifications. Quotations on making finished items involving machining, welding or finishing will be supplied upon request. Equipment is also available for producing simple or complex shapes of Hydrided Zirconium. Finished shapes or conventional mill items are supplied in commercial, reactor grade or Zircaloy compounds. Technical information or counsel will be furnished upon request.

ZIRCONIUM METALS CORP. OF AMERICA
Division of National Lead Company
111 BROADWAY, NEW YORK CITY



Scarfer Rings Used in Radiation Research



Zirconium Metal Cathode

Valve Resists Severe Corrosion

Crucibles Cost Less To Use

Processing belts must withstand destructive forces that ordinary conveying belts never encounter.

When processing is your problem . . . specify
Wissco Woven Wire Belts

There are two general categories of belts. First, belts that merely *convey* products from one place to another under normal conditions. Second, belts that are an integral part of a *process*—where conditions exist such as heating, sudden cooling, corrosion, abrasion, or circulation of gases or liquids. For ordinary conveying, many types of belts will fill the bill. But for processing, just any belt won't do—a *woven wire belt* is the best answer. Here's why Wissco Woven Wire Belts meet your processing requirements:

1. Wissco Belts have an **open mesh**—permitting free circulation or drainage of air, liquid or gases. Corrosive liquids do not stay on the belt. And the open mesh allows rapid and efficient heating or cooling of the product conveyed.

2. Wissco Belts are made of **steel**—plain, tinned, galvanized, stainless or special alloy—to meet temperature extremes, corrosive or abrasive conditions, or operational wear.

3. Wissco Belts are **pretested**, including furnace testing if required, without cost to you. You know your Wissco Belt has operated correctly before you get it.

You also get these Wissco services: belts washed and degreased before shipment, then shipped on a reel (no charge for the reel). A Wissco reel, often replacing several packing crates, saves you freight and handling charges, and makes installation quicker and easier.

Your Wissco Belt engineer is always available to help with your belt installation or operating problems. Contact the CF&I office nearest you today.

WISSCO BELTS
THE COLORADO FUEL AND IRON CORPORATION

CF&I STEEL

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For over a quarter of a century Fahralloy has served the needs of the nation's leading industries with highest quality alloy castings. Whether your particular need is for heat resistant alloy castings or stainless, you can be sure they'll be made to your exact specifications when you place your order with Fahralloy.

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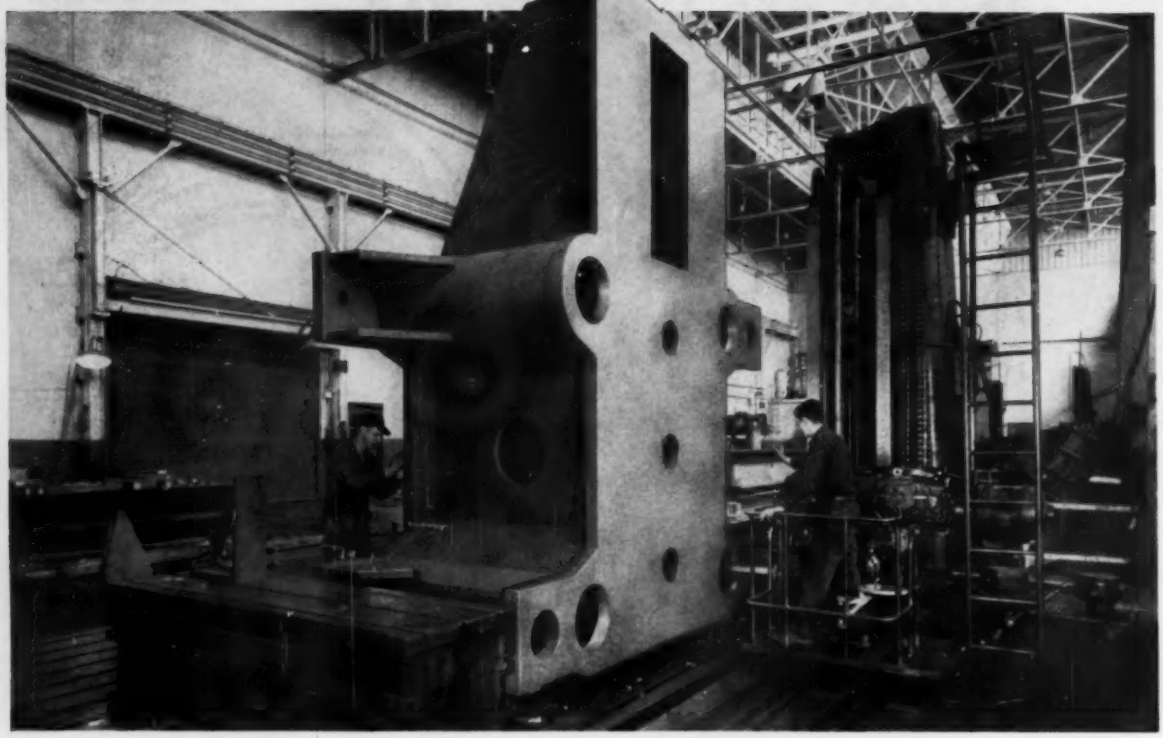
STEEL-WELD FABRICATION . . .



PRECISION WELDMENTS

Fabricated and Machined to Specification!

The 40-Ton Press Bed, undergoing machining operations above, is typical of Mahon workmanship and capabilities in this field. It is one of thousands of Steel-Weld Fabricated parts and assemblies produced by Mahon for manufacturers of processing machinery, machine tools, and other types of heavy mechanical equipment.

When your design calls for weldments of any kind, you, too, will want to discuss your requirements with Mahon engineers; because, in the Mahon Company you will find a unique source for weldments or welded steel in any form . . . a fully responsible source with a long and enviable performance record, and unusual facilities for design engineering, fabricating, machining and assembling.

See Sweet's Product Design File for information on Facilities, or have a Mahon sales engineer call at your convenience.

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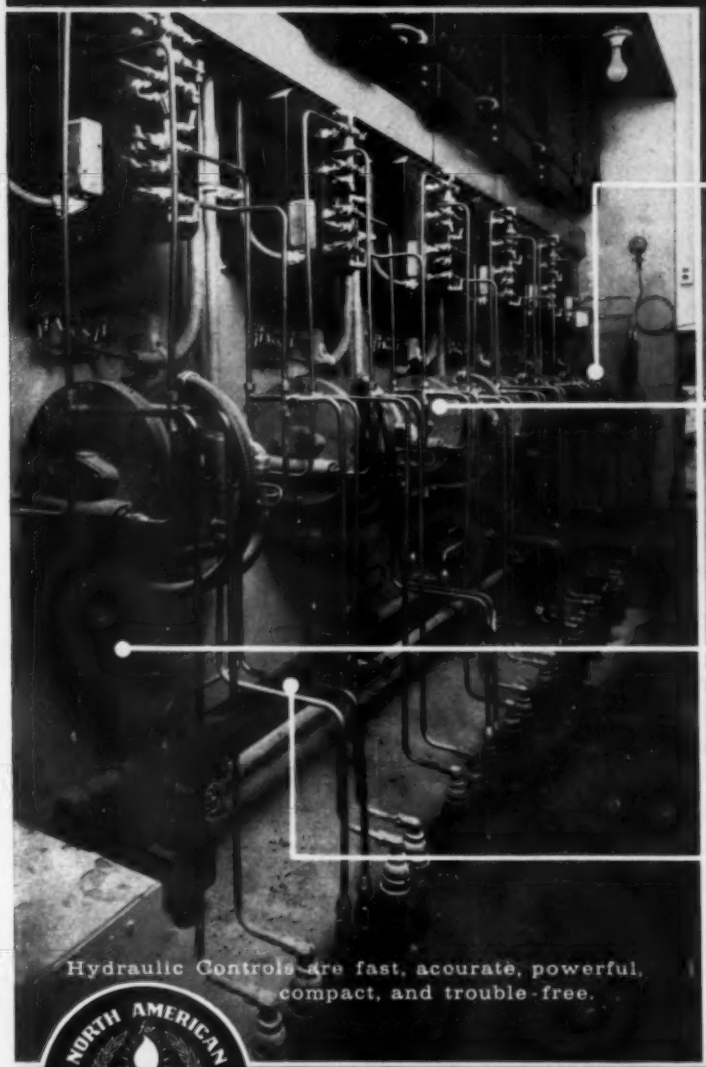
SALES-ENGINEERING OFFICES in DETROIT, NEW YORK, CHICAGO and LOS ANGELES

Use WELDED STEEL for 100% Predictability and Greater Strength with Reduced Weight!

MAHON

Canadian Steel Wheel Ltd. uses combustion controls by North American

60' Rotary Furnace heats 348 blocks (foreground) for press forging railway wheels.



Hydraulic Controls are fast, accurate, powerful, compact, and trouble-free.

Furnace Pressure ±0.0025" wc — controlled by this North American 16" diaphragm Regulator operating the damper on a 60' CANEFCO furnace.

Fuel-air ratio set on control panel for each of 5 zones is *accurately maintained* at all flow rates by North American Regulators. Flow is controlled by North American crank type cylinders on remote fuel valves.

Light weight and compactness allow regulator to be bolted directly on instrument panel without supports. Manual operation is achieved by panel-mounted push-button positioning of the fuel valves.

Pressurized return lines permit low cost installation using small tubing. Pump can be above or below unit.

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6-003
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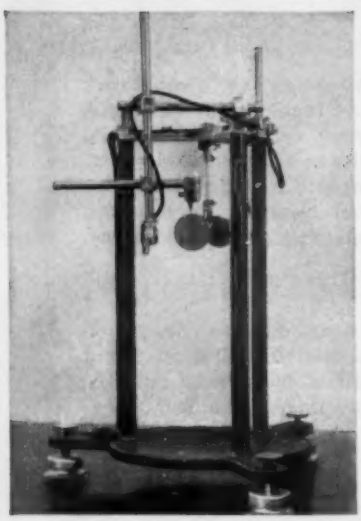
to speed your research programs

Dynamic load recorder makes a permanent record of fatigue tests and stress history of vibrating structures. It also provides a check on both operator and machine, thereby reducing the possibility of errors. Especially valuable for longer tests where a recording oscillograph would require an impractical quantity of recording paper. In zero to 12 cpm range, it plots the complete load cycle with one pen; in the 500 to 4000 cpm range, dual pens plot the upper and lower peaks of the applied dynamic load. Chart speeds: 1, 6 and 12 in. per hour. For more information, send for Product Data 4286.

Torsion Pendulum. Determine torsion modulus and damping characteristics of plastic materials with this precision torsion pendulum. Calibration curves are furnished for the percent crystallinity and density of Teflon* as a function of torsion modulus determined by this device. It consists of a pair of calibrated torsion arms which are suspended from the specimen and made to oscillate by battery-operated electromagnets. Bubble on frame and shockmounted leveling screws permit precise adjustment of vertical axis. For more information, send for Product Data 4181.

*Du Pont registered trademark



Easy-to-operate axial stress fatigue machines (Models AH-5 and AH-20) are especially suited to the testing of bolts, other round threaded devices, fasteners, sheets and chains. Substantial allowable creep permits testing at elevated temperatures. Alternating and static forces are set directly in pounds. Operating controls and instruments are housed in a separate console. Available in two models: 5000 lb. maximum total force (tension or compression) with maximum alternating force of ±2000 lb.; 20,000 lb. maximum total force (tension or compression) with maximum alternating force of ±8000 lb. For more information, send for Product Data 4231.

Self-checking offset yield strength printer speeds production testing—automatically records offset yield strength, extension under load, or yield point, together with tensile strength. Use with any standard B-L-H testing machine. Offset yield indicator circuitry ignores local stress-strain curve irregularities at start of test; rejects data where curve does not have a linear portion adequate to determine slope or where an error exists in equipment setup or operation. Typewriter indexes and advances automatically. For more information, send for Product Data 4285.

Look to B-L-H—makers of the best in testing—for all your testing equipment needs. Consult your B-L-H representative for information about B-L-H's broad line of machines and accessories for tension, compression, creep, fatigue, impact or torsion measurements. Or write Dept. 2-J.

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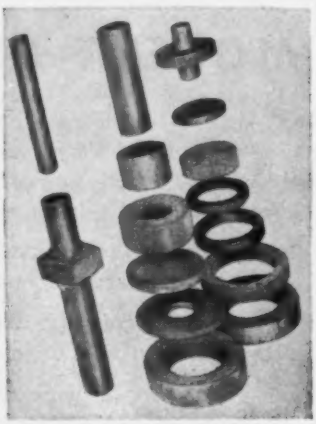

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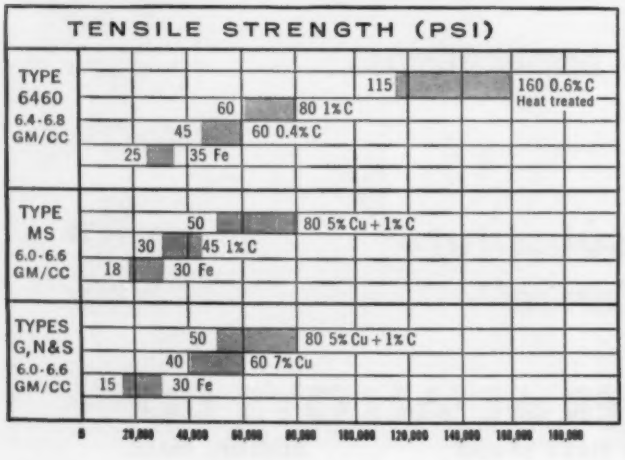

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Booklet, ADV. 1014 contains complete technical information on Types G, N, S, and Type MS. Chemical composition, physical properties, and test evaluations on Type HS6460 are contained in Booklet ADV. 1028. Write for your free copies.

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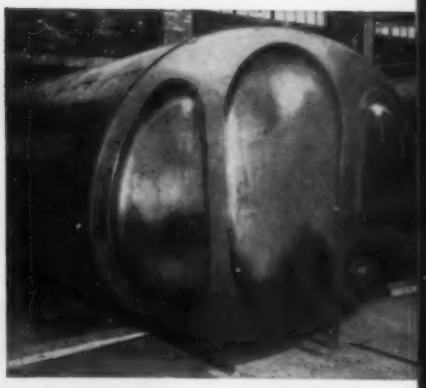

Brownie Stress Distributing Head
fabricated from Youngstown Yoloy "E" High-Strength Steel distributes liquid surge shocks and vertical load within trailer tanks.

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Youngstown Yoloy "E" high-strength steel

This new, rugged Brownie trailer tank train can haul 11,500 gallons of petroleum products in a single trip! Its tank shells and internal stress distributing heads are fabricated exclusively from Youngstown Yoloy "E" Steel. This high-strength, low-alloy steel provides a stronger, lighter rig that carries larger payloads, requires little maintenance.

Brown Steel Tank Company of Minneapolis reports that Yoloy "E" withstands corrosion, resists shock and fatigue, and offers excellent weldability and formability . . . "naturals" for tank builder and user alike.

Wherever high-strength steel becomes a part of things *you* make, the high standards of Youngstown *quality*, the personal touch in Youngstown *service* will help you create products with an "accent on excellence". The Youngstown Sheet and Tube Company, Youngstown, Ohio. Carbon, Alloy and Yoloy Steel.

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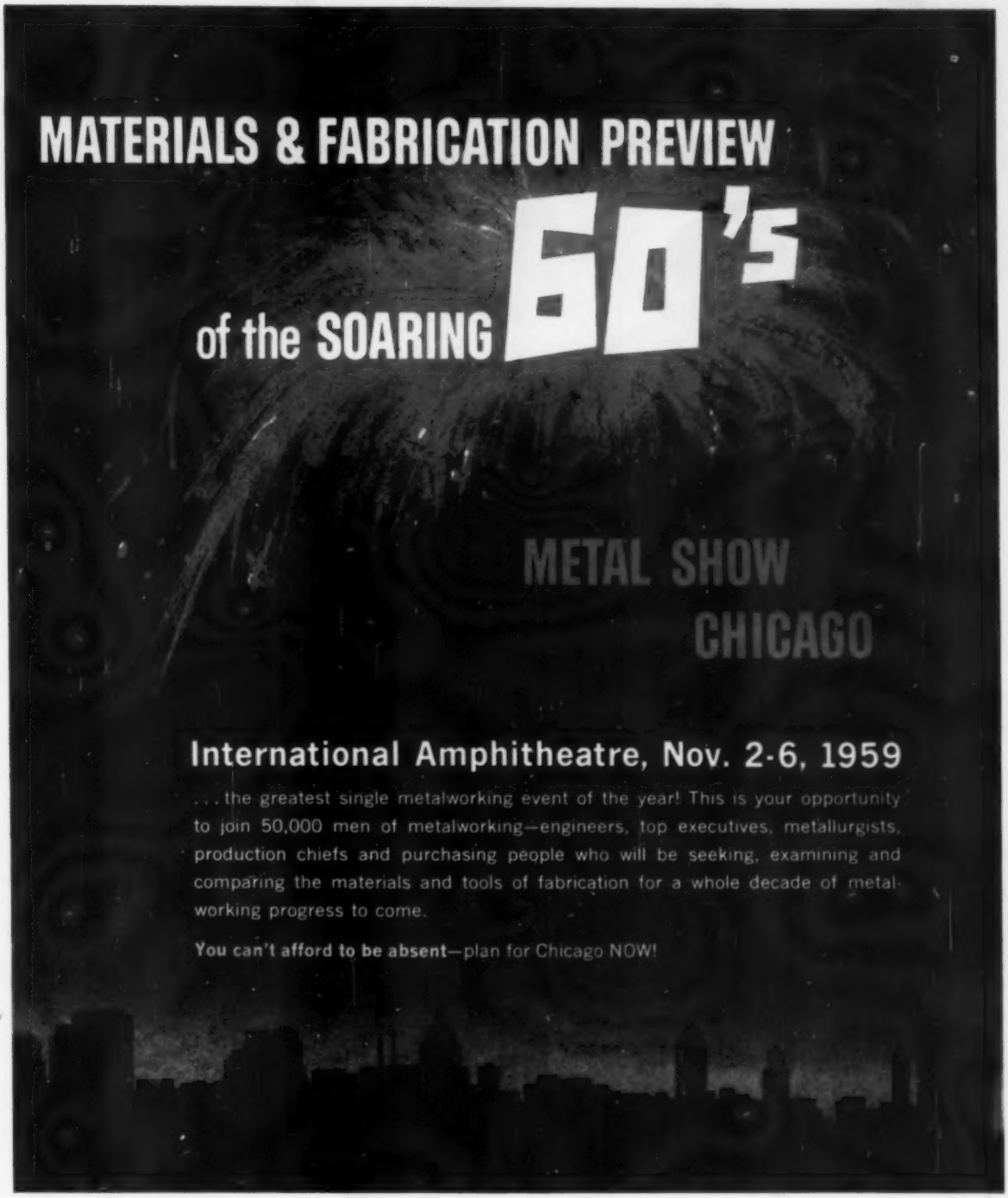
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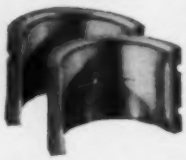
Cast Bronze with centrifugally cast linings of tin or lead base Babbitt. Send inquiry and specifications to Toledo.



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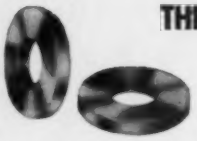

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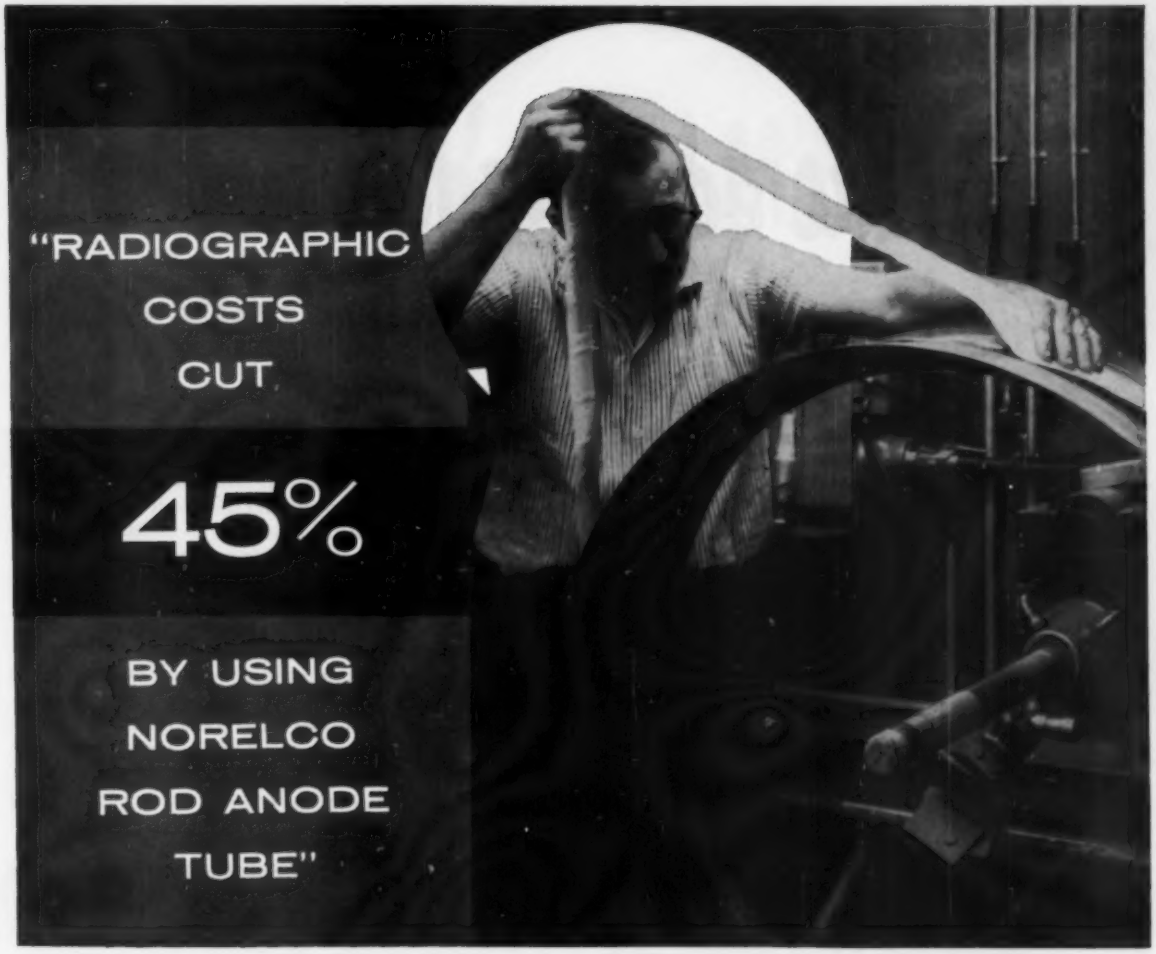

Says Mr. Calvin Esslinger of Kaiser Metal Products, Inc.

Mr. Calvin Esslinger, Section Head of the X-ray Laboratory at Kaiser Metal Products, Inc., Bristol, Pennsylvania, reports, "Using wrap-around film and the NORELCO Panoramic 360 degree Rod Anode Tube reduced our total exposures by 7000 over the period of a year while simultaneously increasing film footage by more than 25%." He further states that the increased production was accomplished with one third the man hours and at a saving of some 200 machine hours!

Part of Mr. Esslinger's inspection program includes radiographic examination of longitudinal and circumferential welds of pressure vessels for guided missiles. The unique rod anode tube which has an effective focal spot of only 1.55 mm., easily exceeds rigid government specifications pertaining to required detail sensitivity.

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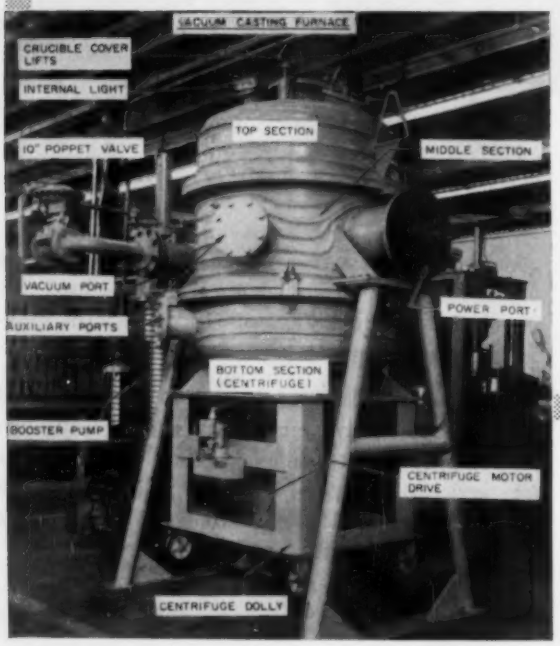
New vacuum methods and techniques—pioneered by Stokes—are finding more and more applications in the metallurgical field. These advances are leading industry out of old impasses . . . while reducing production costs.

Stokes equipment in the nuclear field, for example, has been used to develop new methods for plutonium melting and casting, uranium melting on a production basis, and radioactive materials handling. In another area, Stokes vacuum stream degassing equipment has already helped reduce hydrogen embrittlement in metals . . . is now pointing the way to better "killing" of steel. And still more developments are in the offing . . . in melting, refining, heat treating, sintering and brazing . . . and in Vacuum Metallizing of thin and heavy coatings for both functional and decorative applications.

Stokes experience in the manufacture of components, equipment and systems helps take the guesswork out of your operation. For instance, Stokes can supply a complete turnkey installation—erected, tested and delivered "in operation". Stokes stocks components for faster delivery to eliminate costly holdups. Standard



Radioactive materials handling investigations are safely carried out with this Stokes prototype vacuum furnace. It is remotely operated by manipulators and other external controls. This installation represents another specific requirement met through Stokes flexibility.

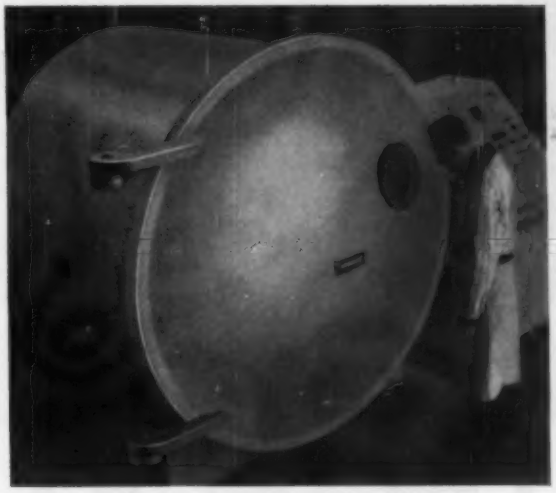
Uranium melting on a production basis is accomplished by this Stokes induction melting furnace. Designed for safety and convenience, the furnace is serviced from the top and features a removable bottom section to facilitate handling of poured materials. It is typical of Stokes inherent flexibility.

Progress in Vacuum Metallurgy

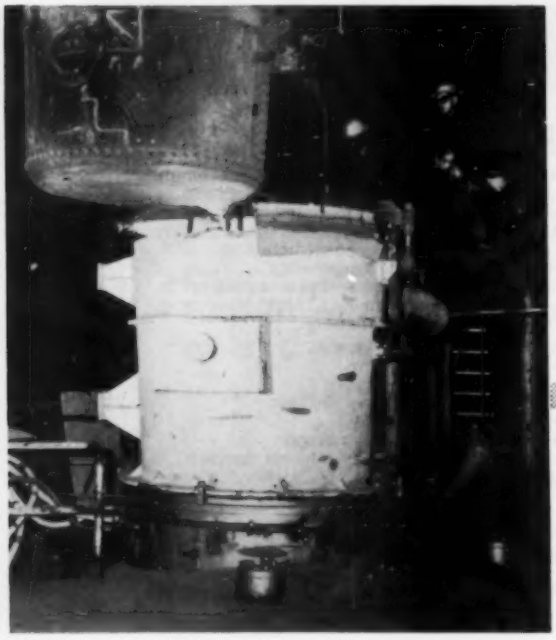
"Single Source" Service

vacuum equipment ranges from small compact R&D models to full production units. Stokes is geared to meet specific customer requirements for many types of special metallurgical equipment. All Stokes systems are offered complete, making Stokes a single source of responsibility for performance and reliability, both before and after the sale.

Let Stokes put its unparalleled experience and facilities to work for you. Stokes' Engineering Advisory Service will assist you in planning and designing an installation that will best serve your exact needs. While it's fresh in your mind, why not call Stokes . . . and get all the details.



Heavy coatings with new continuous sources—cadmium and aluminum—are now possible. Stokes manufactures a complete line of vacuum coaters . . . ranging from small R&D models to this new 72" production unit. Modifications of basic designs are easily made . . . extending applications and system size almost without limit.



First acid open hearth, vacuum stream ladle degassed—Air pouring of multiple ingots in the United States took place at Ohio Steel Foundry in May. Stokes provided the equipment. The results showed low hydrogen values, good inclusion reduction and excellent physical property improvement.

See the Stokes Vacuum Equipment Display—Metal Show—Chicago—Nov. 2-6. Booth #542

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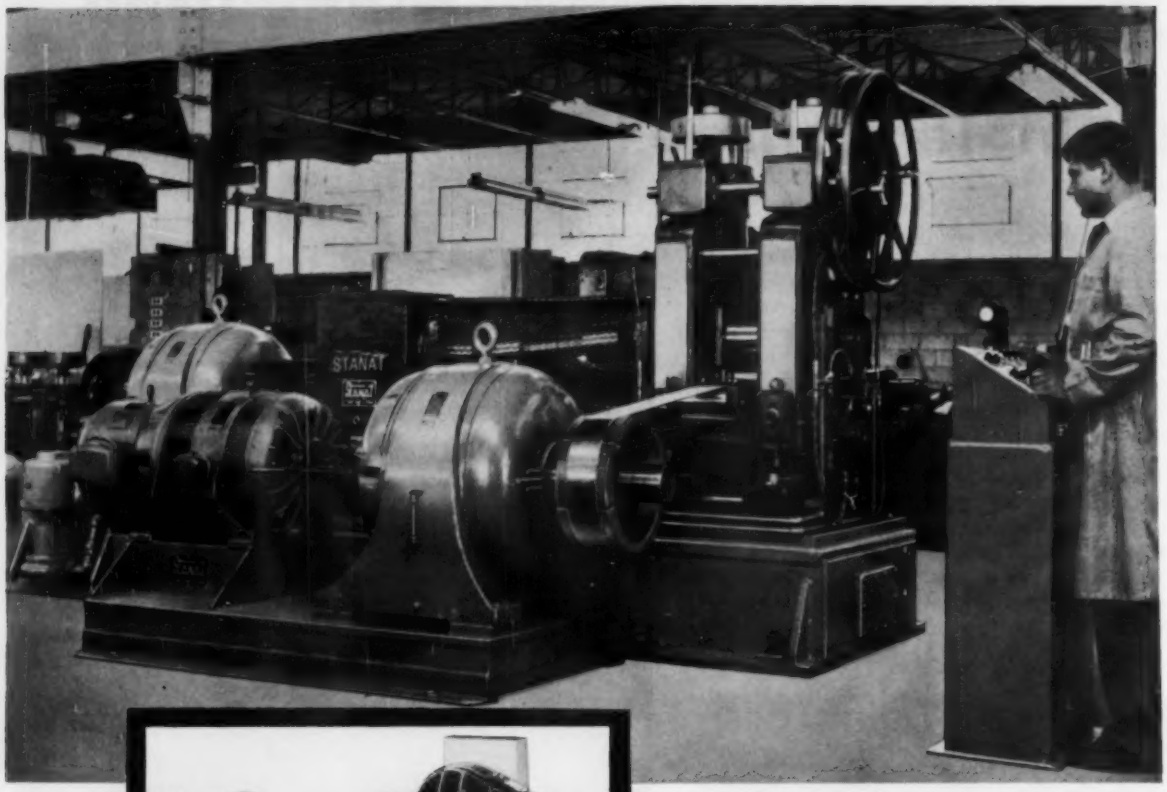
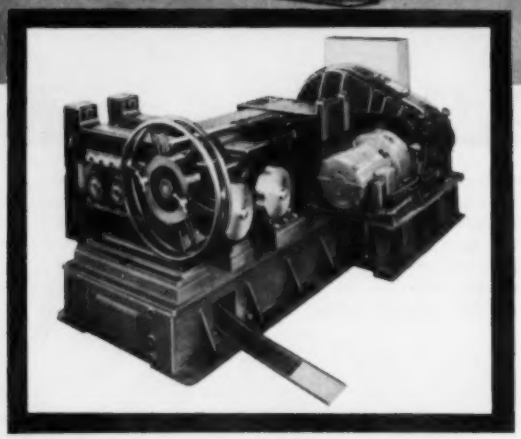
METAL POWDER
ROLLING





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Whatever your present or future requirements, you can now have a single STANAT MILL for any or all of the following...

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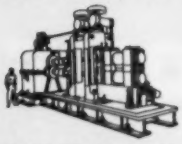
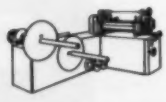
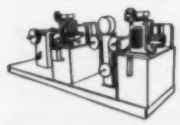
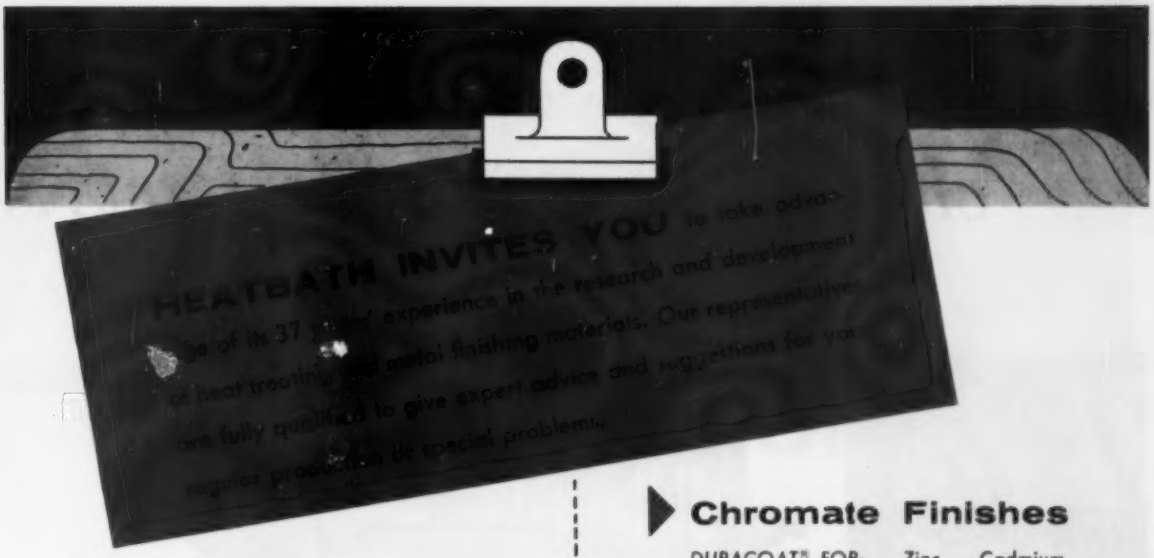




MFR'S OF ROLLING MILLS, GANG SLITTERS, WIRE FLATTENING MILLS, ROLLER LEVELERS AND BULL BLOCKS



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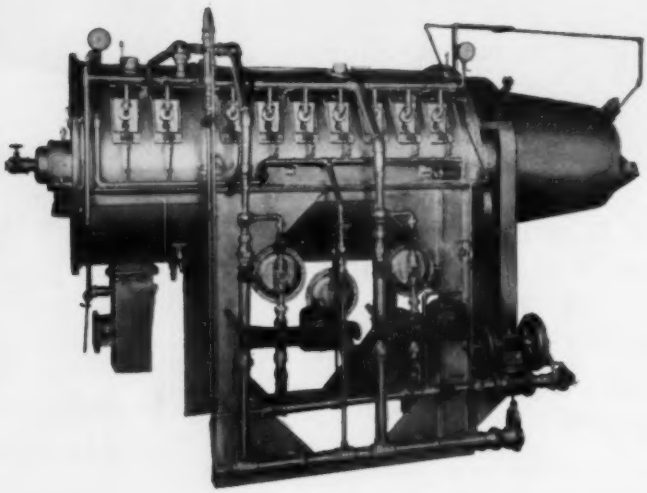
Model 136-M6D

Medium size rotary furnace for the most economical heat treating of parts that can be subjected to a gentle tumbling (approximately ¼ r.p.m.).

Tumbling insures uniform heating and atmosphere contact.



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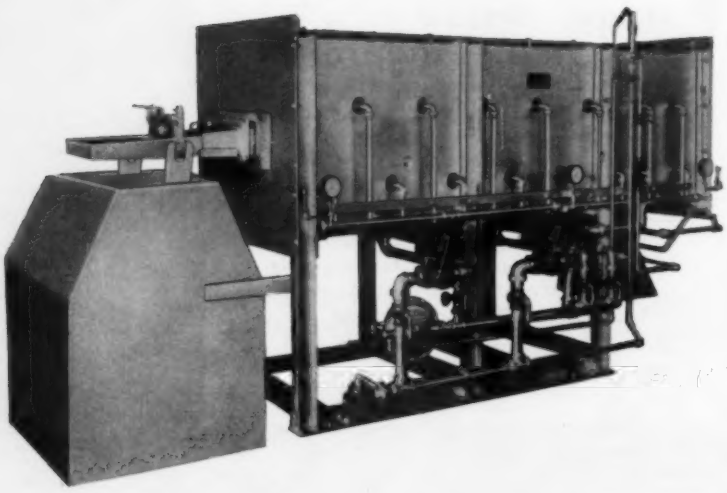
Model 231

Medium size Shaker Hearth Furnace for the widest range of work, even light and delicate stampings.

Momentum imparted to each work piece conveys it individually through the heat with no distortion or warpage.



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ROTARY RETORT

and

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RECIPROCATING HEARTH

for all small parts heat treating

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Capacities to 800 lbs. per hour. Processing pieces from .010" to 1" thickness and up to 10" in length. Automatic continuous feeding reduces direct labor costs drastically! Clean hardening, ammonia-gas case hardening, light case carburizing of steel parts, etc., are accomplished equally well WITHOUT ANY MODIFICATION OF THE FURNACE.

The muffles and retorts are, in reality, radiant tubes WITHIN which the work and atmosphere gas is contained. Zoned combustion systems uniformly heat these muffle tubes from the outside to the desired temperature in each work zone. Control is precise, results uniform.

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Making High Quality Steel—At Low Cost

The growing demand for steels of increasingly higher quality has created a new kind of thinking. With conventional methods of obtaining both high quality and quantity being relatively slow, costly and often uncertain, more and more mills are turning to the modern Heroult Electric Furnace as the most reliable and economical means of making high-grade steel in large heats.

To keep abreast of this trend, Sharon Steel Corporation recently built a complete new Melt Shop at its Roemer Works in Farrel, Pennsylvania, and installed the large Heroult Electric Furnace shown above.

This 20′ diameter furnace turns out 90-ton heats of top-quality stainless in less than 8 hours. Space has been provided for a second Heroult when it is needed.

Moreover, electric furnaces are proving to be more efficient and economical in producing most *any* grade of steel in large or small heats. This is because electric furnace operations require a smaller investment, usually reduce both power and charging costs and produce a more uniform product.

American Bridge, exclusive manufacturers of the Heroult Electric Furnace, offers a complete electric furnace service. We have the facilities to handle the complete job—from foundation to furnace, from engineering to erecting. We are also prepared to modernize your old Heroult by installing improved new mechanisms that will increase the efficiency and productivity of your unit. And, if you own a Heroult, we can supply any needed replacement parts.

For more information, get in touch with the office nearest you.

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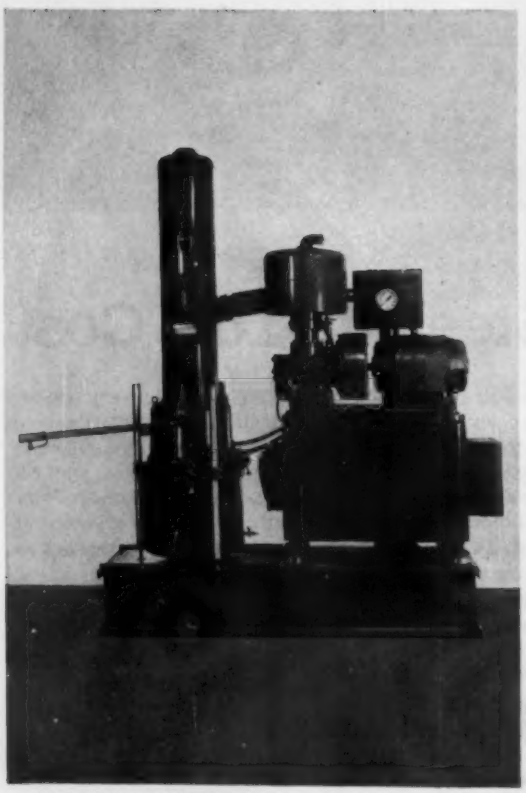
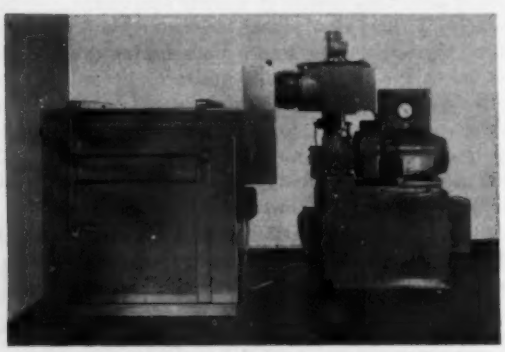
NORELCO

and



NITROGEN GENERATOR – Comprised of a Model A Cryogenerator acting as a nitrogen condenser and an atmospheric pressure separation column. Rate of production is 6 liters per hour over an uninterrupted period up to 200 hours.

AIR LIQUEFIER – This unit liquefies air at atmospheric pressure – thereby insuring a contaminant-free product. Rate of production is 7½ liters per hour.



ENVIRONMENTAL CHAMBER – A specially insulated storage chest is used in conjunction with a Model A Cryogenerator. This permits the production and maintenance of temperatures down to minus 320 degrees F. for environmental testing.

GAS PURIFICATION

GAS SEPARATION

AIR SEPARATION

CONVERSION OF GASEOUS O_2 and N_2 TO LIQUID PRODUCT

METAL TREATMENT

COLD CHAMBERS

LIQUID AIR PRODUCTION

LIQUID NITROGEN PRODUCTION

PRESERVATION OF BIOLOGICALS

COLD MACHINING

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CRYOGENICS

All of the applications listed – and more – stem from the one unit – THE NORELCO CRYOGENERATOR. Available in four different capacities, this remarkable unit consists of a single-stage refrigeration machine designed for operation in the range of minus 320 degrees F. to ambient temperatures. As a basic cryogenic tool, the cryogenerator is completely adaptable to a tremendous number of applications and is in fact being widely used by a host of manufacturers and laboratories throughout the country.

Since the operating principle is identical for all models, specific applications of each depend primarily on the capacity of the system rather than the form of equipment. The four models, designated A, B, C and D, have respective refrigeration capacities of 3,000, 12,000, 40,000 and 160,000 BTU/hr. at minus 320 degrees Fahrenheit.

"Packaged" units consisting of a Model A Cryogenerator with special headers or accessory equipment are also available.

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From the desk of
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C.H.R.—
A new instrument to monitor and control prepared and furnace atmospheres (CO, CO_2, N_2, H_2, O_2, CH_4,) is being displayed by Perkin-Elmer in Space 312 at the Metals Show, Nov. 2-6 in Chicago. Be sure to look it over carefully — could be a big thing for us.
J. M. S.

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write us at 925 Main Avenue,
Norwalk, Conn., for full information.

INSTRUMENT DIVISION
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What Are the Advantages of Electron Beam Welding?

"Un-weldable" is a word to be used with caution. Dissimilar materials, such as aluminum and steel, can now be fusion welded by electron bombardment. Pieces of widely varying thickness can be joined in a single pass. Foil is easy. And weldments, even of reactive and refractory metals, look and perform almost like a solid piece.

These and other triumphs are possible with electron beam welders because:

1. **Operation under high vacuum prevents contamination, eliminates costs and uncertainties of inert gas.**
2. **There is no electrode to contaminate the work.**
3. **Surface oxides are cleaned up.**
4. **Wide variations in total power and in power concentration are easily made.**
5. **Spot size can be varied from 10 mils to more than 6 inches.**
6. **Depth to width ratios of 2/1 are possible.**

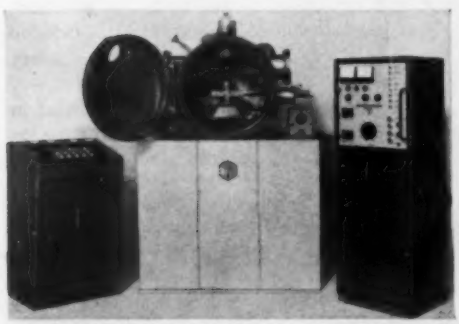
What Have Been the Disadvantages?

In most equipment the electron beam is generated by applying a high voltage between the work and the electron source, with the geometry of the latter focusing the beam. Disadvantages include:

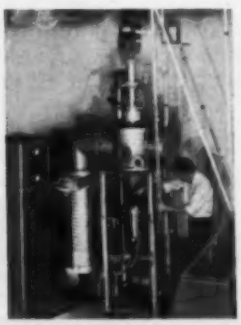
1. **Gas bursts and metallic vapors cause frequent high voltage discharges. At best, these result in annoying interruptions, discontinuous welds, and short source life, and at worst, extensive damage to the equipment. Attempts to reduce discharges by using large vacuum pumping systems and automatic protective devices add greatly to equipment cost and complexity.**
2. **Short focal lengths of ½ to 1 inch pose problems in welding anything but flat pieces and simple cylinders.**
3. **Because the work piece is the anode, the electric field often changes as the weld progresses. This affects the beam and makes precision welding difficult.**

How Has NRC Cured These?

NRC has developed, proved, and applied for a patent on an electron beam welder which is as simple to operate as a television set. It assures complete freedom from high voltage discharges and makes precision welding easy. Work geometry no longer is a problem; even corrugated pieces can be welded successfully. Secret of the NRC Welder's success is its gun design. Special shielding protects the gun against gas bursts and metallic vapors and prevents high voltage discharges. Electro-magnetic focusing makes it easy to change the focal length from 1 to 10 inches and spot size from 10 mils up. Since the area below the gun is field-free, the electron path is unaffected by the shape of the work.



ELECTRON BEAM WELDER Linear or circular welds can be made at speeds of 0 — 0.5 inch per second with the standard Model 2405 Electron Beam Welder. Offered with a choice of 1, 3, or 6 KW power supply, it is easily adapted for end or girth welding.



ELECTRON BEAM FURNACE Reactive or refractory metals can be melted in a standard Model 2460 Electron Beam Furnace to produce ultra high purity ingots up to 3" in diameter and 14" in length. Operation is easy and free from interruption. Special shielding prevents high voltage discharges.

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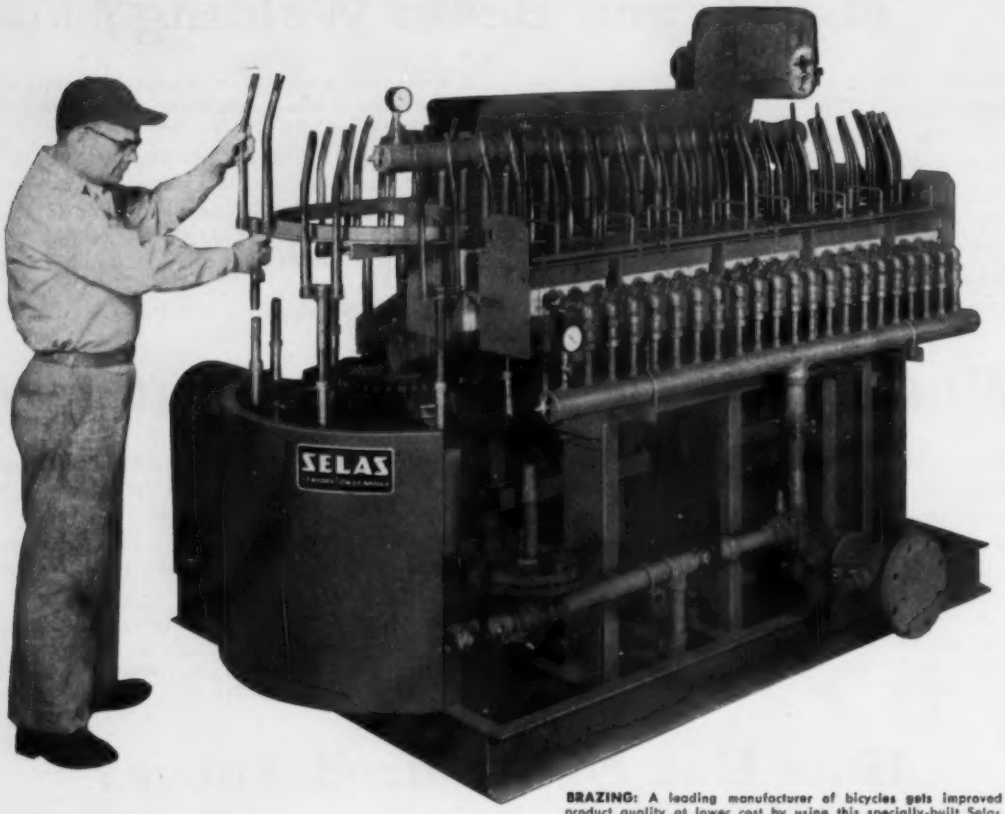
See the NRC Electron Beam Welder at Booth 1227 Chicago Metals Show

IMPROVE YOUR PRODUCT... LOWER YOUR COSTS
...with Selas Automatic Heat Processing



BRAZING: A leading manufacturer of bicycles gets improved product quality at lower cost by using this specially-built Selas automatic machine to braze forks to handle-bar stems. Assemblies, held in fixtures on 5 in. centers, are conveyed through Duradiant®-fired heating zone in a continuous operation. Following heating to 1650°F (the melting point of the brazing alloy), brazed assemblies are air-cooled to solidify the alloy, then water-quenched and cooled at discharge end of the compact (6 x 9½ ft) straight-through machine. Production rate is 300 per hr and fixtures may be adjusted quickly to accommodate various fork and handle-bar stem sizes.

Selas automatic machines are extensively used for production heat processing operations, including annealing, heat treating, brazing and soldering, forging and localized hardening.

The installations shown on these pages demonstrate how Selas automatic heat processing equipment can:

- increase production speed
- save fuel and operating costs
- minimize in-process inventory
- reduce manpower requirements
- save valuable floor space
- improve product quality

Individually designed and custom-built to meet your specific production requirements and job specifications, Selas automatic machines employ time-proven standardized engineering features for longtime operating dependability and minimum initial cost. In addition, you avoid problems usually associated with divided responsibility since Selas starts-up and services every machine it designs and builds.

A Selas automatic machine can prove beneficial in your plant. At your convenience . . without cost or obligation to you . . a Selas field engineer would welcome the opportunity to survey your needs.

For this personal service—or for literature on any of the heating operations shown on these pages—address Dept. 16, Selas Corporation of America, Dresher, Pa.

Duradiant and Gradiation are registered trade names of Selas Corporation of America.

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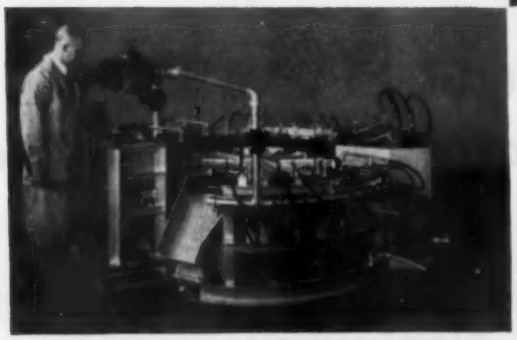
HEATING FOR FORGING: In order to create a more readily saleable product, characterized by fine grain size and better physical properties, a forging shop heats brass slugs with this Selas automatic Gradiation® equipment. Slugs vary in size from ⅞ to 2 in. diam, 2½ to 8 in. in length. Maximum weight per slug is 4 lb and machine heats at rate of approximately 2,000 lb per hr to uniform temperature of 1390°F. Piece production rate for smallest slugs is 800 per hr. Precise positioning on work fixture, typical Selas fast heating and split-second removal of heated slugs from chamber contribute to production of higher-quality forgings.

HEAT TREATING: Designed and built by Selas, this automatic heat processing machine eliminates costly, hazardous lead baths conventionally used to harden stainless steel knife blades. Compact machine (9 x 3½ ft floor space) requires only one operator for entire process. Hand-loaded, blades are quickly brought to 1950°F without scale formation, are uniformly hardened to Rc 42/44 while handle retains full softness to permit design embossing. Angle-mounting permits operator to work at shop floor level; collecting-baskets conform to 4 ft level of existing materials handling system. In addition to saving plant space, reducing manpower requirements and improving safety conditions, Selas machine eliminates two operations: (1) an oil quench and (2) removal of scale and excess lead.

ANNEALING: Unique Selas gas-fired machine anneals brass door knob blanks—automatically in the production line—as part of a completely integrated manufacturing process. Selas Superheat burners fire a narrow jet of high velocity, high temperature gases at a 1⅜ in. band on sidewall of blank. Annealing, cooling and discharge, accomplished in 9 sec, are geared to production line output of 60 finished knobs each minute. Fast Selas heating by non-oxidizing combustion gases achieves a cleaner, brighter end-product . . eliminates need for muffles or prepared atmosphere.



SELECTIVE HARDENING: The end portions of brake shoe webs must be hardened to create a more durable product. Selas automatic machine employs an indexing conveyor which brings just the two ends of webs under Duradiant burners. Designed for automatic loading, the rotary machine heats, quenches, tempers and mechanically unloads the selectively-hardened workpieces. Service life of webs has been materially extended, costs have been reduced by precise heating of selected areas. Burners may be adjusted to accommodate a variety of brake shoe web sizes.

SELAS CORPORATION OF AMERICA DRESHER, PENNSYLVANIA

Heat and Fluid Processing Engineers

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and dynamic balances them, too?

To further National Forge's reputation for producing precise forgings, we've installed one of the largest, most accurate dynamic balancing machines in use. Our American-Trebel has a 33,000-pound, 60-foot capacity.

Pictured on the machine is a 42 ft. propeller shaft that has been forged, machined, and hollow bored—all operations done in our National Forge plant. NF specialists are shown balancing this gigantic 15,500 lb. shaft.

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WF-59-04

For information on the "tough" ones and the machinery that makes them best, write for Bulletin NF 1.

Compact design of Arcweld M-3 Creep Rupture Testers is emphasized here at nationally known research institute. Two rows, including eight Model L's (in rear), use only 338 square feet of floor space. Completely open fronts afford easy operation and loading, allowing machines to be set back-to-back.

UNDER U.S. STEEL FELLOWSHIP

Arcweld Creep Rupture Testers Give Better Temperature Control

Ferrous alloys for new steel to be used in high temperature applications get their pedigree checked by one of the latest developments in the creep rupture tester field.

Specially designed to meet the needs of many creep laboratories which test smaller size specimens or use lighter loads, Model M-3 Creep Rupture Testers from Arcweld Manufacturing Co. are at work in a nationally known research institute under a U.S. Steel Corp. fellowship.

With the help of 30 M-3 and eight Model L Creep Rupture Testers, U.S. Steel plans to develop steels that will have the strength to withstand the stress, strain and elevated temperatures of powerful turbine engines, jet aircraft and missiles.

Richard R. Brady, who is in charge of U.S. Steel's giant Applied Research Laboratory at Monroeville, Pa., played an important part in the choice of Arcweld machines. According to Mr. Brady, Arcweld M-3's were chosen primarily for their design and trouble-free performance.

"These machines are very compact units," he explained. "Each one uses only four square feet of floor space, a very important point in conserving valuable working area."

Two rows of Arcweld machines, set back-to-back, use only 338 square feet of floor space. It is estimated that an equal number of competitive models would use twice as much space. Arcweld M-3 machines have completely open fronts which afford quick, easy loading up to 6,000 pounds. Their exclusive counterbalanced lever systems have a 16 to 1 ratio. The counterbalanced F-6 power positioning furnace produces up to 2,200 degrees Fahrenheit.

"One of the first Arcweld machines I used several years ago was the original Model M Creep Rupture Tester," said Mr. Brady. "I was very satisfied with its ability to perform tests. But now the new Model M-3 gives even better temperature control with precise accuracy.

"In addition to the trouble-free operation of the machines, Arcweld provides excellent service," he continued. "You get the service you want when you need it."

If you have an application for performance-proved, high temperature materials testing equipment, contact Arcweld soon. Complete engineering services are available to help solve your testing problems.

REMEMBER ARCWELD TESTING MACHINES ARE THE LOGICAL CHOICE

ARCWELD MANUFACTURING COMPANY

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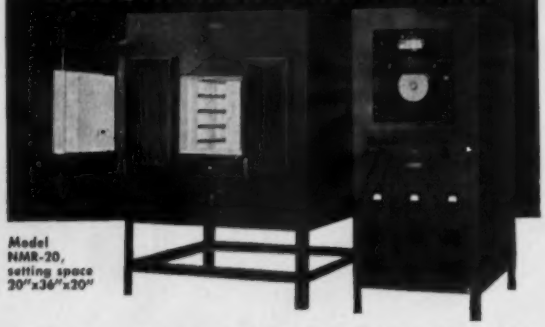
See Arcweld's Booth 735 at November Metals Show in Chicago

Fast, efficient high temperature heating... HARROP Electric Furnaces



Model NMR-20, setting space 20"x36"x20"

When you're judging the value of an Electric Furnace, think in terms of (1) its flexibility in use, its controls, (2) its accuracy in firing, (3) its sturdy, long-lasting construction. When you compare Non-Metallic Resistor furnaces you'll find the Harrop NMR Series:

Flexible. Whatever type of control you require is available. Manual operation, automatic temperature control, repetitive heating to any preselected temperature (with or without adjustable holding time), complete program control. All voltages adjustable from 55 to 230 volts in 36 steps. Specially planned equipment and instrumentation can be designed for your individual need.

Accurate in Firing. Any temperature you require is held within negligible limits of variation, up to 2800° F. continuous operation and 3000° F. intermittent operation.

Sturdy Construction. Full-yoke doors cannot sag or bend out of alignment. 3000° F. internal refractories stand up under hard usage. Housing of heavy steel construction with no projecting switches or other equipment. Heating elements lightly loaded for even heat distribution and long life.

Any NMR Series Harrop Furnace meets most rigid requirements according to the above specifications. Setting spaces range from 7" by 9" by 8½" to 36" by 40" by 36". Special designs can be developed to meet your need . . . for non-obligating recommendations, send information on materials, temperature range, heat control and firing objectives to Dr. Robert A. Schoenlaub, Technical Advisor. **HARROP ELECTRIC FURNACE DIVISION of Harrop Ceramic Service Co.,** Dept. M 3470 East Fifth Ave., Columbus 19, Ohio.

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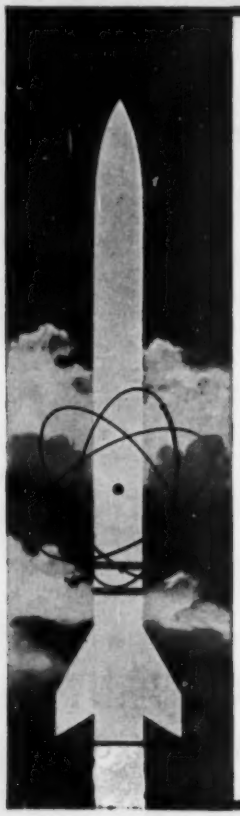

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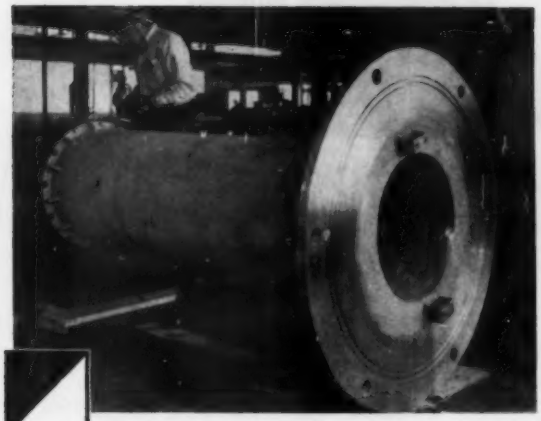

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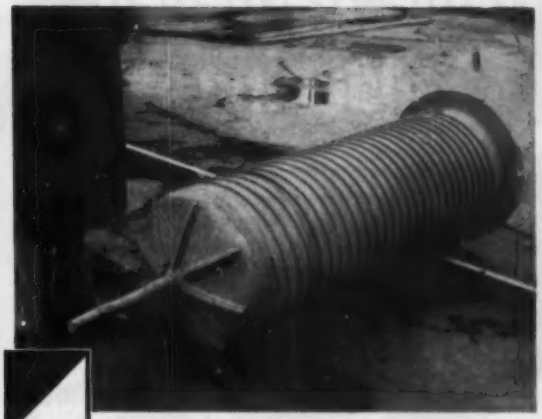

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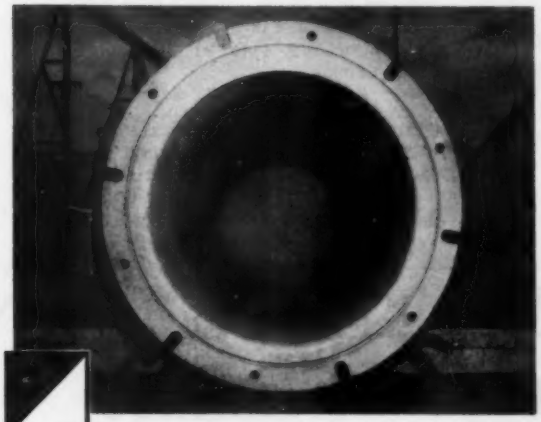

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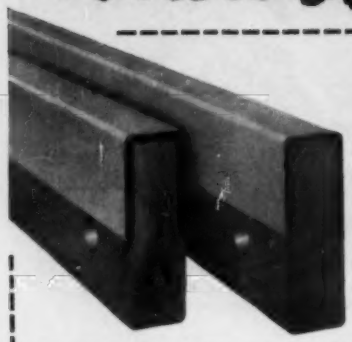

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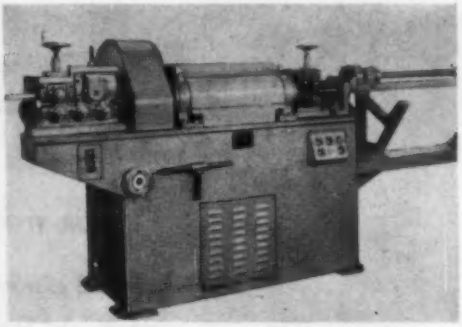

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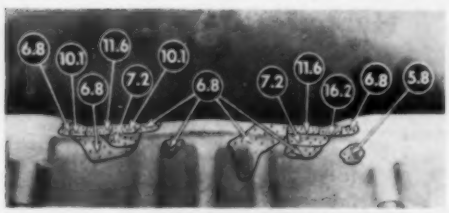

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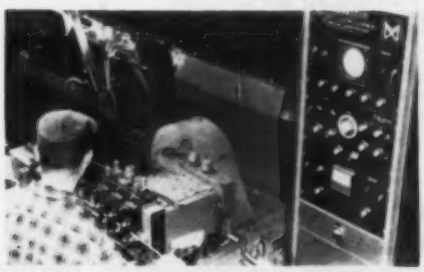

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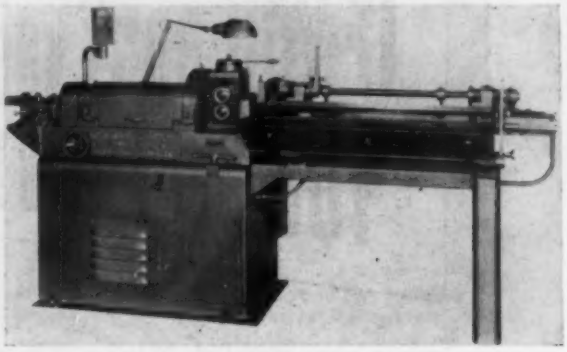

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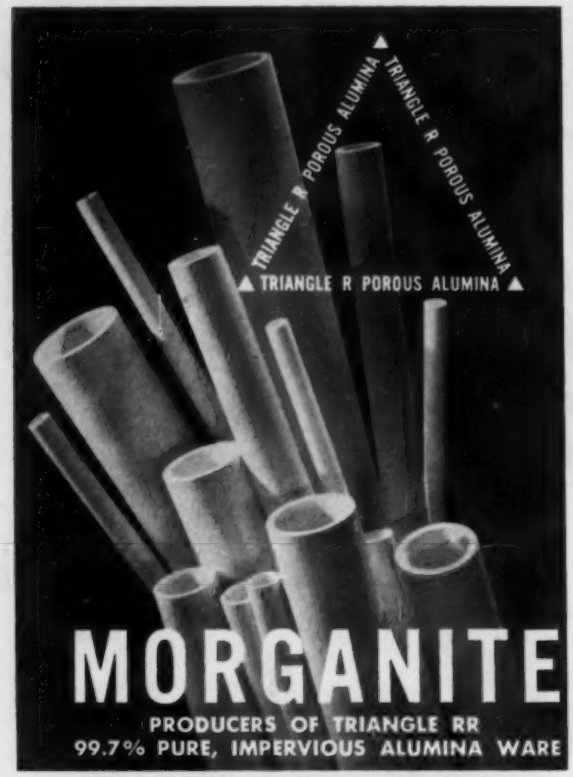
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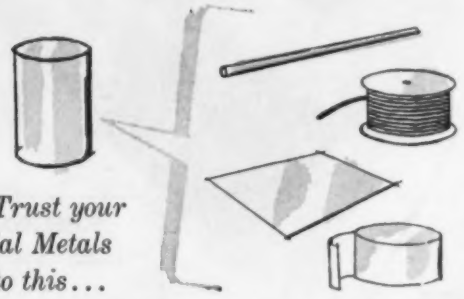

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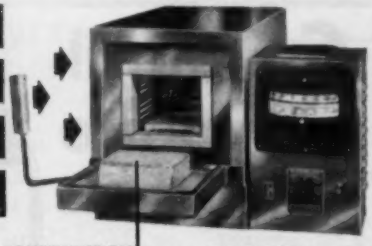

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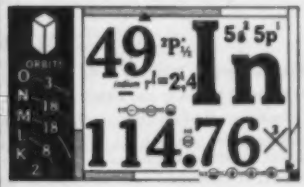

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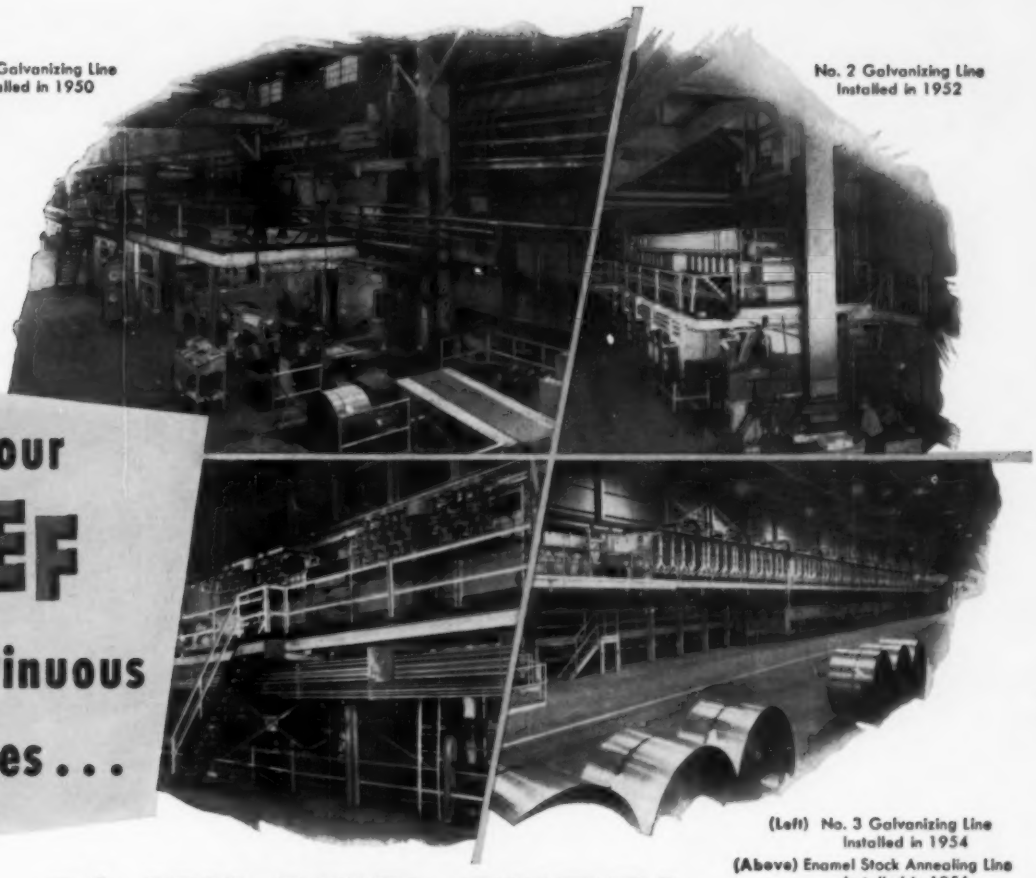

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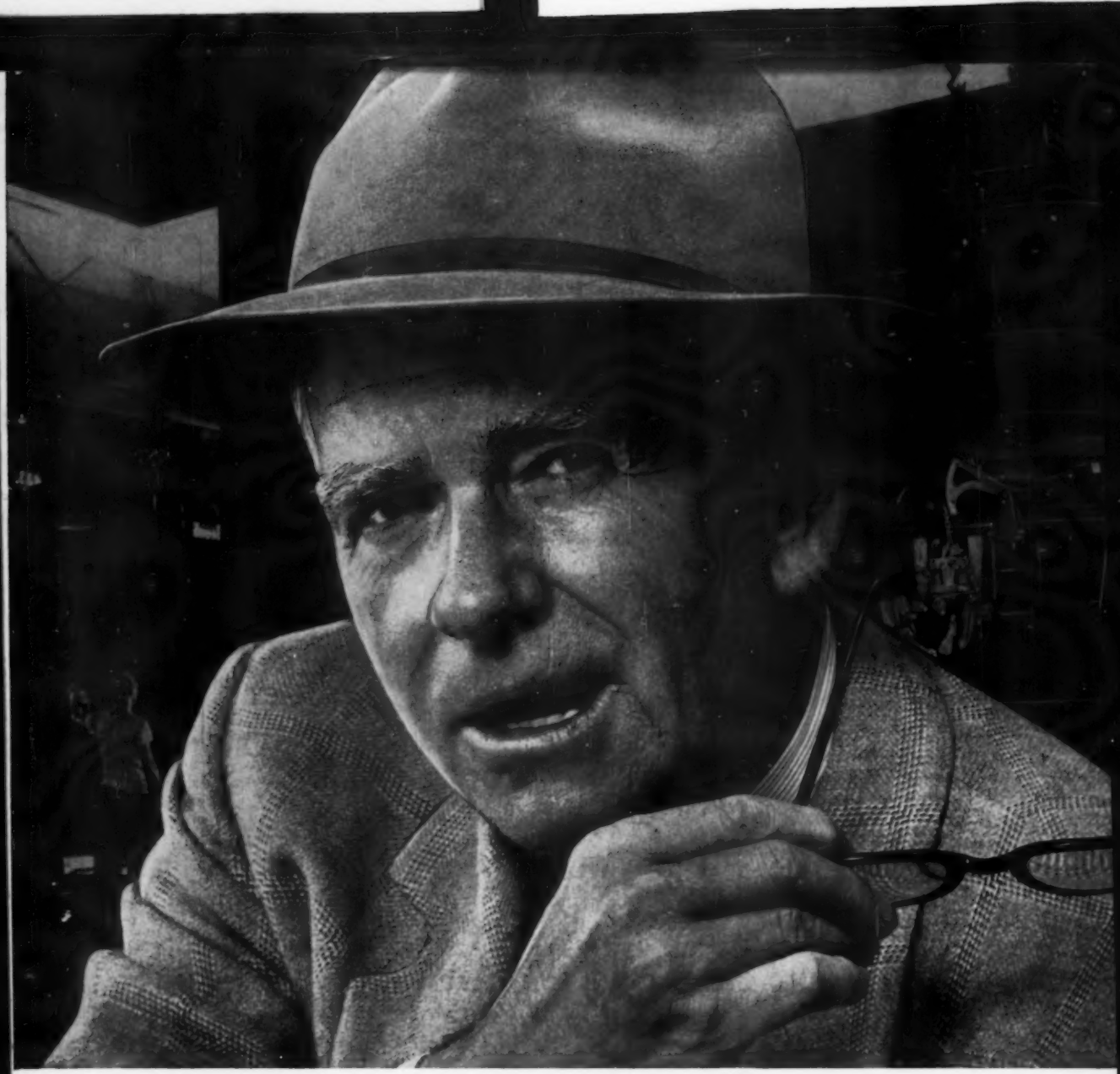

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